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13. SUPPLEMENTARY NOTES

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14. ABSTRACT *(Maximum 200 words)*: The transition to the Objective Force is characterized by challenges, such as how the Army will train, maintain, and operate as an information-age force. A key aspect of the Objective Force is command, control, communication, computers, and intelligence (C^4I) systems. One of the Army's immediate needs is an approach for ensuring that the capacity of digital information systems is fully exploited in combat units, especially among staffs. Staff members must acquire and maintain the skills required on the digital battlefield. Closely linked to training is the need for assessment for feedback and performance improvement, and support for design and development of training programs. Digital C^4I systems offer an exceptional opportunity for efficient and objective methods for staff performance measurement with their potent organic capabilities to collect, analyze, and portray information automatically. This paper describes an effort to develop prototype performance measure output and format that exemplify the potential of digital systems to provide that feedback. Topics covered include a rationale and definition of automated measures and how they relate to measuring skills that staffs and teams need to possess to be successful. The methodology used to design and develop automated measures of staff performance is discussed. Finally, representative results obtained from these automated prototype measures during U.S. Army concept experimentation will be presented, along with lessons learned during this research effort.

15. SUBJECT TERMS

Future Combat Command and Control	Staff Processes	Team Performance	Measures of Effectiveness
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Research Report

Prototype Automated Measures of Command and Staff Performance

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Personnel Performance and
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FOREWORD

The Future Battlefield Conditions (FBC) team of the Armored Forces Research Unit (ARFU), U.S. Army Research Institute for the Behavioral and Social Sciences has a Science and Technology Objective (STO) entitled "Force XXI Training Strategies." The purpose of research under this STO is to develop and demonstrate prototype training and evaluation technologies that prepare operators and commanders to take maximum advantage of evolving digital systems. This STO is also reflected in the FBC work package (2228) FASTRAIN: Force XXI Training Methods and Strategies. Design of prototype commander and staff training packages that use advanced digital technology was completed under previous work. This report describes work under a contract entitled "Performance Evaluation, Training, and Future Requirements for Digital Skills." The purpose of the work described in this report was to develop and evaluate performance assessment tools for future commanders and staffs working in a future digital environment.

This report describes the design, development, and demonstration of prototype automated measures designed to improve training and evaluation for brigade and below command and staff training. The report examines implementation of these measures in a Future Combat Command and Control (FCC^2) experiment at the Mounted Maneuver Battlespace Lab located at Fort Knox, Kentucky.

At least three audiences may be interested in this report. Materiel and training developers could consider hardware and software issues involved in embedding these measures into future command, control, communications, and computer systems. Training unit and training (simulation site) personnel who conduct training of digital staffs could consider these measures for feedback concerning commander and staff performance. Also, measurement specialists and researchers could examine this report to inform further research into the development of automated measures of commander and staff performance.

In addition to this report, products developed under this effort include software to run an Observer Workstation, used to develop automated measures of commander and staff performance during FCC^2. Data gathered during FCC^2 is also contained on the system.

The research reflected in this report was briefed to sponsors throughout the effort and in a final in progress review, held at AFRU, Fort Knox, Kentucky, on 25 July 2001.

ZITA M. SIMUTIS
Technical Director

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This report represents the efforts of an integrated team of research scientists, military experts, training developers, simulation technology experts, and administrative support personnel. The team members directly supporting the U.S. Army Research Institute for the Behavioral and Social Sciences included: military subject matter expertise from Mr. Neff Jenkins, Mr. Mike Flynn, Mr. Bud Dannemiller (Litton PRC), and Mr. Mike Cobb (Human Resources Research Organization [HumRRO]); programming expertise from Mr. Mitch Bonnett (Litton PRC) and Mr. Scott Shadrick (HumRRO); and Ms. Kathleen Horn (Litton PRC) who provided administrative support. Ms. Charlotte Campbell (HumRRO) was the Program Manager for this project. Her contributions went beyond project supervision. She was involved in all project decisions, contributed her expertise as a Research Psychologist, and was a reviewer of this report.

Additionally, we had support and guidance from a variety of individuals and government organizations, including:

- Mounted Maneuver Battlespace Lab, Fort Knox, Kentucky

  Colonel Dennis Szydloski, Chief
  Major Joe Burns, Chief, Advanced Concepts Research
  Major Dan Ray, Concept Integration Officer
  Mr. Joe Jarboe, Systems Analyst

- Illinois Institute of Technology Research Institute (IITRI)/AB Technologies

  Mr. Pat Ritter, Program Director for Research
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  Mr. Don Appler, Site Manager
  Mr. Dan Schultz, Battle Master
  Mr. Paul Monday, Analyst
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PROTOTYPE AUTOMATED MEASURES OF COMMAND AND STAFF PERFORMANCE

EXECUTIVE SUMMARY

Research Requirement:

This research and development effort continues the work by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), Armored Forces Research Unit, Future Battlefield Conditions Team. It focuses on the design and development of automated training and performance evaluation techniques. A primary context for these efforts is digital brigade and below training requirements and environments. For this project, ARI's objective was to design, develop, and demonstrate 20 prototype automated measures to improve training and evaluation for brigade and below command and staff performance.

The prototype automated measures developed were implemented during the Future Combat Command and Control (FCC^2) Concept Experimentation Program experiment conducted by the Mounted Maneuver Battlespace Lab (MMBL) at Fort Knox, Kentucky. The ARI's purpose for participating in this experiment was to support the MMBL and the Army's need to gain additional information on future staff evaluation requirements in a virtual simulation environment, and gather feedback for improvements to the prototype automated measures developed during this effort.

Procedure:

The Project Team reviewed The *Standard Army After Action Review System (STAARS)* handbook (U.S. Army Training and Doctrine Command, 1997) and previous research literature regarding staff processes and measures developed to assess them, especially automated measures. This literature review provided the basis for decisions concerning staff processes to measure, as well as guiding the procedures that the Project Team would use to design, develop, implement, and analyze the measures. A total of 29 candidate automated measures were then designed and presented to a Subject Matter Expert (SME) Advisory Group (SAG) for review. The SAG selected 20 measures for development by the Project Team. The Project Team then built a prototype observer workstation to facilitate the use of the automated measures by trainers and other personnel during after action reviews (AARs).

The prototype automated measures were implemented during the FCC^2 experiment, which took place 7 May through 24 May 2001. The experiment was conducted in the MMBL Mounted Warfare Test Bed at Fort Knox with the 2nd Squadron, 2nd Armored Cavalry Regiment from Fort Polk participating. The Project Team demonstrated 19 of the 20 automated measures it had designed and developed using commercial business software in common use throughout the Army. Development of one measure was not completed during the project.

Findings:

Based on the FCC^2 implementation, additional effort is required to complete the integration of various tools associated with the observer workstation so that raw performance data can be automatically transformed into a finished AAR product. Additional research is required to establish performance standards for future brigade and below battle staffs using advanced command, control, communications, computers, and intelligence (C^4I) systems upon which additional automated measures can be developed. Trained SMEs on staff operations and procedures are still required as observers to provide a context for the results obtained by automated performance measures.

This research effort demonstrated that commercial business software packages operating on low-cost personal computers can be used to design, develop, and implement automated performance measures in a laboratory environment. With additional research, they may be able to support implementation of automated performance measurement in brigade-level and below battle command staffs using advanced digital C^4I systems.

Utilization of Findings:

The specific audience who may find the information contained in this report beneficial includes: (a) measurement specialists and researchers, (b) simulation system programmers (hardware and software), (c) training unit and training site personnel, and (d) personnel conducting the FCC^2 experiment AARs and preparing the FCC^2 experimental final report.

PROTOTYPE AUTOMATED MEASURES OF COMMAND AND STAFF PERFORMANCE

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PROTOTYPE AUTOMATED MEASURES
OF COMMAND AND STAFF PERFORMANCE

Introduction

The transition to the Army's Objective Force is characterized by challenges, such as how the Army will train, maintain, and operate as an information-age force (U.S. Department of the Army [DA], 2001). The foundation of the future Army includes an increased area of operation; increased operational tempo; combining branches for close combat with fewer systems; non-linear, asymmetrical operations; and information dominance with increased situational awareness. A key enabler for this future force will be enhanced commanders' situational understanding, which will flow from the fielding of advanced command, control, communications, computers, and intelligence (C^4I) systems.

Closely linked to the training challenge is the need for measurement, both to allow for feedback and performance improvement and also to support the design and development of the training programs. Measures of performance (MOPs) focused on process, and measures of effectiveness (MOEs) focused on outcome are critical areas of interest. However, direct observation and objective measurement of performance during training are difficult, particularly for command and control (C^2) performance. Subjective methods used for assessing C^2 performance are labor-intensive approaches, requiring observers with high subject matter expertise. Even with automated data collection aids such as electronic clipboards or computer-assisted observation tools, these methods are inefficient. They are also subject to unreliability because of the lack of standardization among observers. Measurement problems are further exacerbated in the information-intensive environment of digital C^2. Observers, like users and participants, can be quickly overwhelmed with the amount of information relevant to C^2 performance.

Digital C^4I systems, however, offer an exceptional opportunity for more efficient and objective methods for performance measurement, particularly for C^2 performance. Digital C^4I systems have organic capabilities that should allow us to exploit them to automatically collect, analyze, and portray data. As Goehring (1995) states:

> What distinguishes this approach [automated analysis by computer systems] from previous software tool development efforts is that most of the work of the researcher or analyst is actually accomplished by the computer software. After careful formulation of the problem and codification, the actual analysis is accomplished automatically. The difference from the past is somewhat subtle. Previously, software tools processed and presented refined information to the investigator, who then further analyzed the information. Now because of several technological developments it is increasingly possible for much of the second phase of the work to be accomplished fully automatically. In the first case, the computer helped to do the work. In the second case, the computer does all the work! (pp. 4-5)

Integrating commercial business software into digital C^4I systems may be a low-cost way to allow trainers, commanders, and observers who are not computer programmers to design their own automated performance measures. As these commercial business software packages are becoming more capable and sophisticated, their ease of use and relatively low cost has led the Army to widely distribute them. Increasingly, every soldier is being provided access to desktop computers that use business software to accomplish routine tasks. These soldiers are also experimenting with ways to use this software to collect, process, analyze, and disseminate information about performance.

Capitalizing on this broad-based knowledge and familiarity with operating commercial business software may be a bridge to automating performance measurement using C^4I systems. Although outcome information (i.e., MOEs) is commonly automated, more work is necessary for process information (i.e., MOPs) to reach the same level (Salas, Bowers, & Cannon-Bowers, 1995). The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has sponsored a series of research projects with the objective of automating performance measurement, particularly for battle staffs equipped with advanced digital C^2 systems. This report details the assessment methodology work performed for an ARI-sponsored contract project titled, "Performance Evaluation, Training, and Future Requirements for Digital Skills" and referred to herein as DC^4I-3. The research effort was conducted by a project team consisting of personnel from the Human Resources Research Organization and Litton PRC (hereafter referred to collectively as the Project Team).

Specifically, the objective of the DC^4I-3 research project was threefold: design, develop, and demonstrate prototype automated measures to improve training and evaluation for brigade and below command and staff training; design, develop, and demonstrate prototype training techniques that incorporate principles of cognitive psychology and automated performance assessment and feedback; and identify research issues and training approaches for the future force with a focus on embedded staff training and multi-functional leaders and soldiers. This report documents the design, development and demonstration of the prototype automated measures of command and staff performance.[1] The original prototype automated measures package was designed for "Refinement of Methods for the Training and Assessment of Digital Staffs (DC^4I-2)," and is described in the report *Refinement of Prototype Staff Evaluation Methods for Future Forces: A Focus on Automated Measures* (Throne, Holden, & Lickteig, 2000).

There are many benefits to using automated measures, some of which are outlined in Throne et al. (2000). Most importantly, as command staffs rely on computers in their work, the more important it will become to assess their computer interactions as meaningful aspects of work process and outcome. Second, automated measures are objective measures of performance – they present "unchallengeable 'ground truths' " (Brown et al., 1997, p. 3). Third, a greater reliance on automated measures may increase the scope and precision of performance assessment and feedback. Fourth, automated measurement and analysis may be needed for more complex work settings, such as C^2 staff performance. Fifth, unobtrusive and automatic data collection may reduce measurement error and increase the accuracy of the information presented during

[1] For more information on the prototype training techniques, see Deatz and Campbell. (2001). For more information on the research issues for the future force, see Campbell and Holden (2001).

after action reviews (AARs). Finally, automated data collection will reduce observer workload and resource requirements. Current AAR presentations can be very labor-intensive and products are often requested late in the battle, which makes them difficult to prepare in time for the AAR (Anderson, Begley, Arntz, & Meliza, 2000). Automated measurement will allow these products to be produced in a more timely manner, allowing observers to focus on other activities, such as evaluating overall performance and providing coaching and mentoring where needed (Morrison & Meliza, 1999).

Although employing automated measures is beneficial, they should not be the only form of evaluation used. A comprehensive measurement package should also include the traditional types of performance evaluation, such as observations, surveys, and interviews. Automated measures are the least studied aspect of a well-rounded measurement package and should only be used as a complement to the other types of measurement. In addition, automated measures provide measures of what happened, not why it happened. In order to provide a stronger link between outcomes and processes, more information would be needed than that provided by automated measures alone. This project focuses solely on automated measures because other aspects of measurement are more fully developed. Additionally, a complementary package of traditional measures (e.g., survey, observer, and interview questions) was already developed during the original project entitled "Prototype Methods for the Design and Evaluation of Training and Assessment of Digital Staffs and Crewmen," and referred to as DC^4I (Throne et al., 1999).

Organization of the Report

This report has five major sections:

- *Introduction.* Organization of this report as well as summary of previous research and relevant literature on team performance and evaluation. Includes a discussion of staff processes, measures of staff processes, automated measures of command and staff performance, and conclusions.

- *Method.* Description of the measures development process, including front-end analysis, design, and development of automated measures of command and staff performance. Also includes a description of the Future Combat Command and Control ($FCC^{2)}$ participants, materials, and implementation of the developed measures.

- *Results and Discussion.* Representative results from developed measures and discussion of automated measures evaluation and implementation for FCC^2.

- *Lessons Learned: Improve.* Summary of the major lessons learned concerning implementation of automated measures during Mounted Maneuver Battlespace Lab (MMBL) experimentation.

- *Lessons Learned: Sustain.* Principles that should sustain future research and development efforts on the use of automated measures to assess command and staff performance.

Appendix A contains a list of the acronyms and abbreviations used in this report. Appendix B contains a description of the FCC^2 setting. Appendix C contains the key aspects of the prototype automated measurement package, including operational definitions, rationale, and recommended output formats for the candidate automated measures. Appendix D contains a sample automated measure macro.

Background

The purpose of the Background is to provide the context for the DC^4I-3 project and the rationale for the automated measures approach to evaluation. A brief summary of the previous work conducted for the DC^4I and DC^4I-2 projects and the lessons learned from each are provided. The environment in which the DC^4I-3 research was implemented is also described. For a review of additional research related to automated measures of command and staff performance, see Throne et al. (2000).

DC^4I Research

The development of automated measures of performance was only a small portion of the original DC^4I project. The goal of the project was to develop a prototype C^2 staff training and assessment package. For the assessment portion, the Project Team developed not only automated measures, but also surveys, interview questions, and an Observer Data Collection Instrument (Throne et al., 1999).

In order to develop effective C^2 staff performance measures, the term "staff" had to be defined. Since information about automated measures of command and staff performance is limited, the DC^4I Project Team redefined staff performance as team performance, since a military staff could be viewed as a team. Therefore, the definition of teams developed by Salas, Dickinson, Converse, and Tannenbaum (1992) was used to refer to a staff. They define team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership" (p. 4).

Since the measurement package was to be implemented during the Battle Command Reengineering (BCR) III, the Battle Lab Experiment Plan (BLEP) for the BCR III (MMBL, 1998) was examined as a starting point for evaluation. In the BLEP, several research issues or questions related to advanced digitization's effects on battle command at brigade and below were identified that could form the basis for developing future staff training performance standards. Since the future battalion battle staff model that the Project Team was using did not have published doctrine or tactics, techniques, and procedures upon which to base training and performance evaluations, the MMBL issues were used as a starting point.

A total of 14 automated measures were designed to support six issues that the Project Team felt could be partially addressed by automated processing of BCR III data. The intent was to use the data collection and analysis capabilities of the MMBL to automatically produce the output formats, which consisted of tables and graphs. This approach did not work and to produce the results for the issues, a considerable amount of additional data examination, editing, processing, and subsequent analyses also had to be accomplished by the DC^{4}I Project Team. The measure tables and graphs were manually created using Microsoft® Excel with no automated data processing involved.

The most important lesson learned from the DC^{4}I research was that by specifying the output format of the automated measures, the researcher will greatly reduce the programmer's work in extracting data from the C^{4}I system. Output format specification will also provide the programmer a greater understanding of what the researcher is looking for in the measures. By providing the programmer both the operational definition of an automated measure and the specific format in which it is to be reported, the programmer will be better able to meet the expectations of the researcher (Throne et al., 1999).

DC^{4}I-2 Research

For the DC^{4}I-2 project, automated measures of command and staff performance became the focus. An opportunity to implement these measures was provided by BCR IV, which took place in April, 2000. By participating in the BCR IV, the Project Team had the opportunity to conduct a trial implementation of the automated measures of performance. Coordination between ARI and the MMBL at Fort Knox, Kentucky, enabled the two organizations to work together as a team to accomplish multiple goals. The Project Team used the preliminary automated measures developed for the DC^{4}I project as a starting point. For this second project, since there already was a clear understanding of what constitutes a team, the next step was to establish aspects of positive team performance in order to determine what to measure. Consequently, the Project Team decided to institute a framework around which to develop the measures. The Project Team needed to determine what kind of processes to measure that would provide an indication of level of staff performance.

After a literature review, the Project Team found that one of the most thorough evaluations of team processes was conducted by Cannon-Bowers, Tannenbaum, Salas, and Volpe (1995). These authors conclude that there are eight skill dimensions common to most team-based tasks. The definitions given by Cannon-Bowers et al. are provided in Table 1. As corroboration, the U.S. Army Training and Doctrine Command (TRADOC) Regulation 350-70 (DA, 1999) lists team skill requirements very similar to those outlined by Cannon-Bowers et al. Therefore, the Cannon-Bowers et al./TRADOC framework of team process skill dimensions was implemented. However, after careful deliberation, only six of the eight skill dimensions were selected as potential candidates for being partially addressed by automated measures. The two dimensions not selected, Leadership/Team Management and Interpersonal Relations, were considered either to be more of an individual skill or to require observer input in order to be measured.

Table 1

Cannon-Bowers et al.'s Team Process Skill Dimension Definitions

Team Process Skill Dimension	Definition
Adaptability	The process by which a team is able to use information gathered from the task environment to adjust strategies through the use of compensatory behavior and reallocation of intrateam resources.
Performance Monitoring and Feedback	The ability of team members to give, seek, and receive task-clarifying feedback; includes the ability to accurately monitor the performance of teammates, provide constructive feedback regarding errors, and offer advice for improving performance.
Shared Situational Awareness	The process by which team members develop compatible models of the team's internal and external environment; includes skill in arriving at a common understanding of the situation and applying appropriate task strategies.
Leadership/Team Management	The ability to direct and coordinate the activities of other team members, assess team performance, assign tasks, motivate team members, plan and organize, and establish a positive atmosphere.
Interpersonal Relations	The ability to optimize the quality of team members' interactions through resolution of dissent, utilization of cooperative behaviors, or use of motivational reinforcing statements.
Communication	The process by which information is clearly and accurately exchanged between two or more team members in the prescribed manner and with proper terminology; the ability to clarify or acknowledge the receipt of information.
Coordination	The process by which team resources, activities, and responses are organized to ensure that tasks are integrated, synchronized, and completed within established temporal constraints.
Decision-Making	The ability to gather and integrate information, use sound judgment, identify alternatives, select the best solution, and evaluate the consequences.

Note. Adapted from Cannon-Bowers et al. (1995), pp. 344-346.

Once the framework was selected and the processes to be measured were defined, the Project Team needed to define the phrase "automated measures." However, very few researchers had developed automated measures and most of those who had were measuring either individual performance or outcomes of team performance, not processes. Those few who had measured team performance automatically (e.g., Atwood et al., 1991; Leibrecht, Meade, Schmidt, Doherty, & Lickteig, 1994) had not provided a specific definition of what constitutes an automated measure of team performance. Therefore, based on the literature reviewed, the Project Team developed its own definition. Automated measures were defined as measures based on data collected from a C^4I system and processed automatically by preformatted routines to provide meaningful training and performance assessment feedback with as little observer input as possible. The C^4I system data was further defined to include, but not limited to, voice communications, simulation protocol data units (PDUs), electronic messaging, C^4I system usage, situational awareness information, and observer input.

The first step in the design process was to select candidate measures for development. For each of the six team process skill dimensions chosen, multiple candidate measures were identified in order to obtain supporting data on that particular skill dimension. Candidate measures were selected from those implemented during the BCR III, measures developed by other researchers (e.g., Dzindolet et al., 1998; Mason, 1995), or based on the lessons learned from BCR III discussed in Throne et al. (1999). All candidate measures were designed so their outputs could be displayed in at least one of these three formats: tables, graphs, and pictures, with an emphasis placed on pictures.

Once the candidate measures were designed, they were passed to the Subject Matter Expert (SME) Advisory Group (SAG) for review and approval. The SAG was a committee consisting of participants from the MMBL, the MMBL Core Support Group, ARI, and the Project Team. This group was organized during DC^4I-2 in an attempt to include programmers, SMEs, and researchers in the entire measures design and development process. Based on the SAG's feedback, the Project Team met with MMBL system programmers to begin developing the higher priority measures. After meeting with the programmers, some of the priority measures were considered to be too time-consuming or expensive to develop, given the BCR IV time and cost constraints. Of the 30 candidate measures, 19 measures were selected as feasible for development, given the BCR-related costs and time constraints. These measures are summarized in Table 2.

Table 2

Automated Measures Developed for Battle Command Reengineering IV by Skill Dimensions

Skill Dimension and Measure Name	Description
Adaptability	
Terrain Analysis	Amount of time each duty position uses each of the following tools: Stealth Control, Terrain Intervisibility, FOV, Snail Display, and FLOT Display during the mission.
Performance Monitoring and Feedback	
SITREP Use	Frequency and duration of use of the SITREP tool during each mission by duty position.
SPOTREP Use	Frequency and duration of use of the SPOTREP tool during each mission by duty position.
CCIR	Frequency and duration of use of the CCIR tool during each mission by duty position.
Information Retrieval by the Commander	Type and frequency of information the Commander retrieves on his own that other staff normally retrieve for him.

(table continues)

Table 2 (Continued)

Skill Dimension and Measure Name	Description
Shared Situational Awareness	
Map Area	Square kilometers of the battlefield displayed and center point of each resized PVD map during each mission by duty position at critical points in time.
Line of Sight	Frequency and duration of use of the Line of Sight tool during each mission by duty position.
Surprise Attack	Total number of flank or rear engagements on OPFOR and BLUFOR vehicles during each mission.
Collateral Damage	Total number of attacks on BLUFOR non-instrumented vehicles and/or personnel by indirect non-line of sight weapon systems under battalion control during each mission.
Communication	
Whiteboard Use	Total number of Whiteboard files residing on each workstation for each mission by duty position.
Radio Communications Pattern	Frequency and duration of use of battalion command and operations-intelligence radio nets and Whiteboard conferencing during each mission by duty position at critical points in time.
Personnel Initiating Whiteboard Conferences	Total number of Whiteboard conferences, lasting 3 minutes or more, initiated during each mission by duty position.
Coordination	
Overlay Use	Total number of workstations showing the same operations overlay file that the Squadron Commander is showing on his PVD for each mission by duty position at critical points in time.
Whiteboard Commonality	Total number of Whiteboard directories showing the same Whiteboard files that the Commander and Deputy Commander have for each mission by duty position at critical points in time.
Targeting	Total number of times a SPOTREP query was conducted on the target identified in a fire support request immediately before it was transmitted by a staff member.
Fire Support Coordination	Ratio of OPFOR kills due to indirect fire from units controlled by the squadron staff to OPFOR kills due to direct fire controlled by squadron subordinate units.
Fire Engagements	Average range of OPFOR and BLUFOR kills by vehicle type during each mission.
OPFOR Destruction	Time from the first OPFOR engagement until OPFOR vehicle losses exceeded 70%. In addition, the rate at which the OPFOR was killed in 5-minute intervals from the first engagement until the last OPFOR kill during each mission.

(table continues)

Table 2 (Continued)

Skill Dimension and Measure Name	Description
Decision-Making	
UAV Effectiveness	Percentage of OPFOR vehicles first detected by the UAV under squadron control for each UAV launch during each mission.

Note. BLUFOR = blue forces; CCIR = commander's critical information requirements; FLOT = forward line of own troops; FOV = field of view; OPFOR = opposing forces; PVD = plan view display; SITREP = situation report; SPOTREP = spot report; UAV = unmanned aerial vehicle. From *Refinement of prototype staff evaluation methods for future forces: A focus on automated measures*, by M. H. Throne, W. T. Holden, Jr., and C. W. Lickteig, 2000, Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Unfortunately, since the pictorial and graphical representations for a majority of the automated measures could not be supported by the MMBL's programming analysts due to time constraints, the automated measures outputs provided were in tabular form (Throne et al., 2000). However, the Project Team attempted to develop prototype pictorial formats for some of the measures based on the data tables. These picture formats were all developed by the Project Team using a commercial off-the-shelf spreadsheet software program, Microsoft® Excel. This was a time-consuming process since iterative experimentation with the picture formats was required to relate data tables to the operational context.

In summary, although a prototype automated measurement package of team process skills was developed for DC^4I-2, true implementation of automated measures as defined by the Project Team was not achieved. Nevertheless, considerable progress was made in matching Data Collection and Analysis System (DCA) output data to team process skill dimensions and a start was made on converting the measures data into automated pictorial representations of staff performance (Throne et al., 2000).

Current Project

For the current project, the Project Team was directed to design 25 prototype automated measures and then select 20 for development and implementation. These prototype measures could either be new measures or measures refined from the DC^4I-2 project, since the measures from that project were not truly automated. The goal was to produce as many measures in pictorial format as possible, since pictures are a good way to present complex measures of command and staff performance in a manner that is simple to interpret (Meliza, Bessemer, Burnside, & Shlechter, 1992). As mentioned previously, although this report focuses on the use of automated measures, they should be used as one aspect of a complete measurement package.

An opportunity was provided to implement the prototype automated measurement package during the MMBL's Concept Experimentation Plan, FCC^2, previously known as BCR. A description of the $FCC^{2,}$ including experimental objectives, is provided at Appendix B. The Project Team had extensive experience operating in this environment and felt that there would be significant advantages to continue to work with the MMBL. Among these are:

- Army Battalion Staff Participation. An intact, trained staff from a maneuver battalion would be participating in FCC^2. This staff would replicate the rank structure and operational experience of soldiers on future battle staffs.

- Surrogate Command, Control, Communications, and Computers (SC^4) System. Staff members in FCC^2 would be equipped with individual SC^4 systems that are digitally networked to share information. Each SC^4 workstation is equipped with: an electronic map that displays automatic updates of friendly and opposing forces' (OPFOR's) location and status; e-mail messaging; collaborative mission planning tools, including electronic Whiteboard conferencing; voice communications; and a computer-generated virtual display of the battlefield, to include terrain information and both friendly and OPFOR vehicles and personnel. Conceptual designs for future Army C^4I systems include most of these capabilities. A complete description of the SC^4 system can be found in Throne et al. (2000).

- Instrumentation and Data Collection System. Data to create the automated measures could be generated by the MMBL's DCA during the virtual simulation used in the FCC^2. The DCA is a set of tools designed to collect, reduce, and display information on battlefield performance, command and control, communications, and other types of data in distributed simulations. Again, based on prior efforts, the Project Team had extensive knowledge of the type of information the DCA could produce, and what its strengths and limitations were.

- Experimental Objectives. The FCC^2 experiment was designed to examine the effects of digitization on battle command at brigade and below. This supported the DC^4I-3 project's main objective, which was to design, develop, and demonstrate prototype automated measures to improve training and evaluation for future brigade and below command and staff training

Method

This section provides both the measures development and the measures implementation processes. The measures development process includes information on the front-end analysis, measures design, and actual measures development. The measures implementation process includes information on how the measures were implemented during the FCC^2.

Measures Development Process

The measures development process is an iterative procedure that requires extensive collaboration among researchers, SMEs, and programmers. The process implemented by the Project Team consisted of 12 basic steps:

1. Review lessons learned from previous work
2. Identify candidate measures
3. Select 25 for potential development

4. Draft definition and output format
5. Categorize by team process skill dimension
6. Meet with the SAG to select measures
7. Specify definition and output format for selected measures
8. Develop software code and run on previous BCR data files
9. Assess input and output
10. Repeat steps 7 through 9, as required
11. Develop Observer Work Station
12. Add measures and outputs to DCA Library

The front-end analysis stage consisted of steps 1 and 2; the measures design stage consisted of steps 3 through 7; and the measures development stage consisted of steps 8 through 12. The steps are discussed by the stages in more detail below.

Front-End Analysis

The front-end analysis of the measures development began with a look at the lessons learned from the previous project (Throne et al, 2000). These lessons learned provided direction for the refinement of the automated measures implemented in the previous project as well as ideas for new measures that might provide meaningful feedback. A brief summary of the lessons learned is provided below.

One lesson learned was that an iterative process for designing, developing, testing, and refining automated measures is required to get useful results. Programmers, SMEs, and researchers need to follow up on all measure outputs to make certain the end product meets everyone's expectations. For the current project, iterative collaboration was more fully integrated into the design and development process.

Another important point is that data reduction is a time-consuming process. During the design and development process, the Project Team had projected that various summary tables would provide the desired results with little additional processing. However, in analyzing the initial results, the Project Team needed to refilter the data tables or go back to the raw data to get the desired measure output. There is a trade-off between getting the most meaningful measures output and having a fully automated measures development system. In a fully automated measures development system, data reduction would not be as time-consuming, yet the data used may not always provide the most meaningful output. One of the main purposes of this project was to more fully automate the measures development and output process.

After incorporating the lessons learned into the measures development process, the Project Team identified potential measures for development. The team looked for measures that could be automated and focused heavily on measures that could be delivered in a pictorial format. The ARI requirement was to design 25 automated measures, with at least 4 from the C^2 measures outlined in the *Standard Army After Action Review System (STAARS) After Action Review (AAR)*

Handbook (TRADOC, 1997) and at least 11 from the measures developed during the previous project. Therefore, the team reviewed the TRADOC handbook and the work done on the DC^4I-2 project.

Measures Design

Measures were reviewed and selected based on whether they were relevant to the BCR environment, could be automated without the need of an observer, would be of interest to a commander, and could possibly be depicted in a pictorial format. From the STAARS handbook (TRADOC, 1997), 12 potential measures were chosen, including 4 from the C^2 battlefield operating system (BOS). An additional 8 potential measures were chosen from the DC^4I-2 project. Finally, 9 measures were chosen that appeared in both the STAARS handbook as well as in the DC^4I-2 project. These 9 measures were essentially measuring the same things although they may have had different names and/or output formats. For example, the STAARS handbook contains a measure named fratricide, which was called collateral damage in the DC^4I-2 project. In summary, there were 12 unique STAARS measures, 9 STAARS/DC^4I-2 measures, and 8 unique DC^4I-2 measures, for a total of 29 potential measures.

Once these 29 measures were selected, operational definitions, rationale, and sample output formats were produced for each. Operational definitions and rationale were adapted from the STAARS handbook (TRADOC, 1997) as well as from those developed for the DC^4I-2 project. Measures that had been implemented during the BCR IV were evaluated for their output formats. The original outputs provided in the STAARS handbook were also evaluated for meaningfulness. Those that were determined to be meaningful and could not be improved were used for the current project as sample output formats. Measures that did not provide very meaningful outputs were redesigned to provide the desired information in the best possible format.

The next step was to integrate the STAARS measures with the DC^4I-2 measures and categorize them under a single framework. Whereas the STAARS measures are classified by BOS, the DC^4I-2 measures were classified by the team process skill dimensions discussed earlier. The Project Team again opted to use the Cannon-Bowers et al. (1995)/TRADOC (DA, 1999) framework since it had provided a meaningful base on which to build the measures for the previous project. Through discussions among researchers and SMEs, measures were individually categorized by the skill dimensions. Although some of the measures may have fit under more than one skill dimension, they were categorized according to the skill dimension for which they were most relevant.

The operational definitions, rationale, and sample output formats were then passed along to ARI for evaluation and approval. After evaluating the measures, ARI deleted several of the measures that dealt with tool use, added a few new measures, and refined the output formats for some of the remaining measures. This review process led to 24 proposed measures. Figure 1 shows the 24 candidate measures presented under the team process skill dimensions framework.

Adaptability
- Node Locations (D)
- CSS Locations (S)

Communication
- Orders Distribution (D/S)

Coordination
- Damage to BLUFOR/OPFOR Systems (D/S)
- Degradation of Forces (D/S)
- Subordinate Unit Graphics (S)
- Overlay Use (D)
- Counterreconnaissance Effectiveness (S)
- Artillery and Counterfire Radar Coverage (S)
- Kill Distance (D)
- Sensor-Shooter Time Lag (D)

Decision-Making
- Sensor Coverage (D/S)
- Multiple Fire Engagements (D)
- Maneuver Battle Sets (S)
- CSS Available Over Time (S)

Performance Monitoring and Feedback
- Priority Intelligence Requirements (D)
- Common Map Display (D)
- Effects of Targeting (S)

Shared Situational Awareness
- Map Area (D)
- Surprise Attack (D)
- Fire Support Coordination (D/S)
- Air Defense Coverage (S)
- Fratricide/Collateral Damage (D/S)
- Common Picture (D)

Note. D = DC^{4}I-2 measure; S = STAARS measure; D/S = DC^{4}I-2 and STAARS measure.

Figure 1. Proposed measures categorized by team process skill dimensions.

These refined measures were then given to the SAG for evaluation. After reviewing the measures, the SAG met and provided ratings on which measures should be developed now, developed later, or not developed. The Project Team consolidated the ratings and selected the top 20 measures, which all fell into the first two categories, for development. Table 3 shows the top 20 measures selected for development. The operational definitions, rationale, and recommended output formats for these measures can be seen in Appendix C.

Table 3

Selected Measures Categorized by Team Process Skill Dimensions

Skill Dimension and Measure Name	Description
Adaptability	
Node Locations	Location of each node in relation to major subordinate units at a specified time period.
CSS Locations	Location of types of CSS assets at a specified time period.
Communication	
Overlay Use	Compares Commander's operation overlay files usage with key unit personnel during each mission.

(table continues)

Table 3 (Continued)

Skill Dimension and Measure Name	Description
Coordination	
Damage to BLUFOR/ OPFOR Systems	Number and type of BLUFOR/OPFOR systems out of action and what damaged or destroyed them during each mission.
Degradation of Forces	Depiction of the relative combat power of maneuver forces over time for both BLUFOR and OPFOR during each mission.
Counterreconnaissance Effectiveness	Effectiveness of the BLUFOR counterreconnaissance effort during each mission.
Artillery and Counterfire Radar Coverage	Range of BLUFOR artillery (by unit or type) coverage at a specified time period.
Kill Distance	Distance between OPFOR/BLUFOR weapon system killed and BLUFOR/OPFOR system that killed it during each mission.
Sensor-Shooter Time Lag	Time between first detection of OPFOR HVT/HPT by BLUFOR and when the OPFOR HVT/HPT was killed during each mission.
Decision-Making	
Sensor Coverage	Range of BLUFOR artillery (by unit or type) coverage at a specified time period.
Multiple Fire Engagements	Number of OPFOR vehicles which were engaged multiple times during each mission.
Maneuver Battle Sets	Disposition of OPFOR and BLUFOR at a specified time period.
CSS Available Over Time	Availability of ammunition and fuel during each mission.
Performance Monitoring and Feedback	
Effects of Targeting	Depiction of HVT/HPT and the degree of attrition each suffered during each mission.
Shared Situational Awareness	
Map Area	Square kilometers of battlefield displayed for each staff member at a specified time period.
Surprise Attack	Depiction of BLUFOR in relation to OPFOR when BLUFOR were attacked for flank or rear engagements during each mission.
Fire Support Coordination	Total number of artillery and/or mortar rounds fired during each mission.
Air Defense Coverage	Depiction of air defense system range templates overlayed on the location of the unit's critical assets at a specified time period.
Fratricide/Collateral Damage	Depiction of the location, unit(s) involved, and results of fratricide and collateral damage during each mission.
Common Picture	Difference between electronic map displays at a specified time period.

Note. CSS = combat service support; BLUFOR = blue forces; OPFOR = opposing forces; HVT = high value target; HPT = high priority target

Measures Development

The Project Team's goal was to develop fully automated measures of performance using commercial off the shelf (COTS) software. In addition, the measures development process would be presented through a user-friendly medium that would require very little if any programmer expertise to implement. To accomplish this, the measures development process was twofold: development of the measures themselves and development of a prototype observer workstation through which observers could develop the desired measures for AARs. Both of these efforts are described in more detail below.

Automated measures. Once the definitions and output formats had been specified for the measures, the next step was to select a software package that could transform the data that would be produced by the DCA into the desired format. For all the DC^4I efforts, the DCA output provided to the Project Team has been in the American Standard Code for Information Interchange (ASCII) format. The data in this format is readily imported into Microsoft® Excel, which has been used to create tables and graphs. The Project Team decided to continue to use Excel as the measures creation tool for several reasons. Excel has an integrated chart wizard that could produce the majority of the desired output formats without a need for extensive programming. The chart wizard would work in conjunction with a macro recorder so that the same type of chart or graph could be repeatedly generated using different data sets without having to go through a step-by-step process for creating each output. Changes to the design of the measure output format would be easy to make. Charts and graphs created with the Excel wizard could be further customized using the Microsoft® Visual Basic® for Applications programming language, which is included with Excel. The output formats could then be seamlessly moved to other Microsoft® Office products, such as Word for reports or PowerPoint® presentation graphics program for presentations.

Once the Project Team had settled on using Microsoft® Office as the baseline software package, development of the measures was initiated using BCR IV data available from the DC^4I-2 project. Early on, it became apparent that additional data would be required to support the new measures that had been designed for the current project. The Project Team generated a listing of the data elements that would be required to support each measure. Coordination then was effected with the MMBL to obtain the required additional data. Based on the Project Team's experience with BCR IV data, some initial decisions were made to facilitate data handling and subsequent analysis: vehicle locations were to be provided at 5-minute intervals; status of ammunition and fuel were to be provided at 20-minute intervals; only weapon system kills were to be reported; engagements that resulted in misses or less than a catastrophic kill would be excluded; only OPFOR weapon systems that were detected by the unit and its subordinate elements would be reported; and the MMBL would package the data into three separate files to prevent the mixing of incompatible data types.

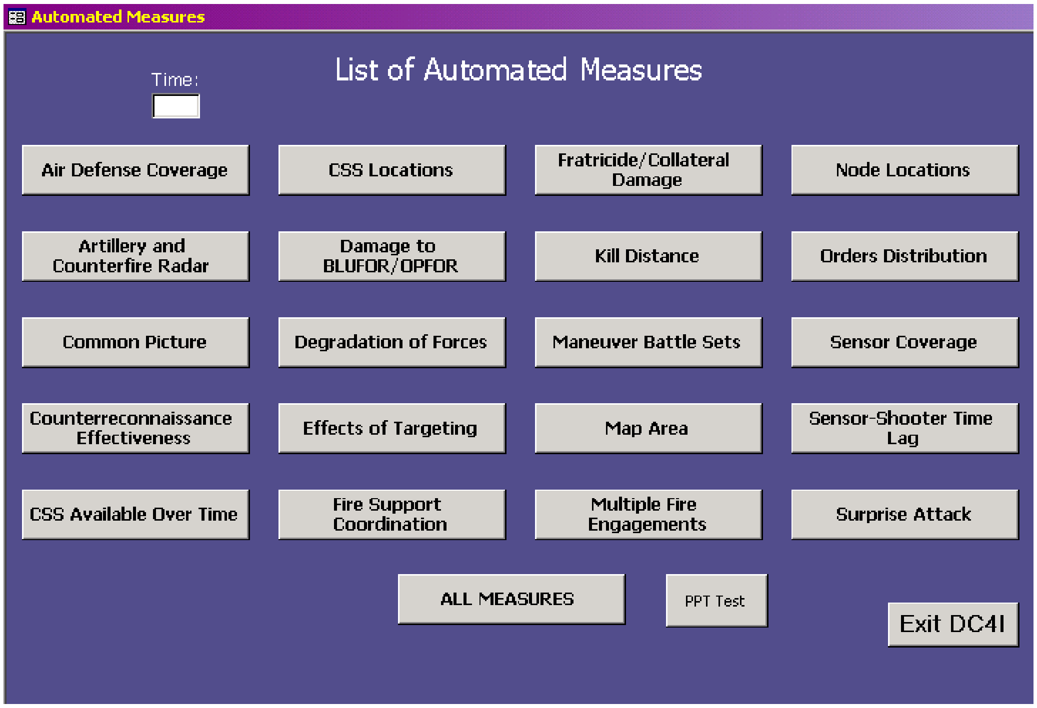
As the Project Team began to work with the additional data, it became apparent that the size of the data files would exceed the capabilities of Microsoft® Excel. For example, in the sample BCR IV data set, an average mission contained 175,000 rows of data with approximately 50 columns (i.e., variables). Excel could only handle approximately 66,000 rows of data.

Therefore, the Project Team decided to use Microsoft® Access for data manipulation while continuing to use Excel to create the charts and graphs.

Once the MMBL ASCII data files were imported into Microsoft® Access, the Project Team built queries for each of the picture, graph, and table output formats. Queries in Access are designed to return only the data the user requires from the larger data file. Multiple queries were often necessary to return all the data required to build a specific measure. The Project Team found that it was easier to manipulate several small data files to create a Microsoft® Excel chart or graph than to work with one large complex data file. Additionally, since some of the measures had more than one output format, even more query files would be required. To handle the growing number of queries, the Project Team created Access macros that would control running the queries associated with each measure. Therefore, while the Project Team developed 66 queries, there were only 20 macros – one for each of the 20 developed measures.

Once the macros were developed, a form was constructed in Access that appears automatically when the file is opened (see Figure 2). The form does three things. First, it provides the user a link to Access through a user-friendly interface that will be incorporated into the Observer Workstation. In this way, the user will only see a button for each of the 20 measures, and not all the queries that need to be run in order to develop a measure. Second, it allows the user to set the time for which the output data files would be created. Once the user enters the time and clicks on a button, the required data to build the measure(s) are automatically output to Excel. This is especially critical for those output formats that are essentially snapshots in time. For each change in time, queries would be required and the form provides a simple mechanism for setting the time for all queries. Finally, the form gives the user an option of selecting one or all of the measures at one time

To create the measure output formats, the Project Team began by using the Microsoft® Excel chart wizard, which was described earlier. All operator actions used to create the chart or graph were captured by a macro recorder. The macros were then modified using Microsoft® Visual Basic® in order to achieve the desired format. In many instances, this meant overriding the various Excel default chart or graph characteristics. For example, a gridline pattern that represented the terrain database was added to the pictorial. Standard chart colors and symbols were aligned with Army standards. Background and foreground colors were eliminated or modified. Additional Visual Basic® software code had to be written to work around some of the data series limitations of Excel. An example of an Excel macro modified with Visual Basic is provided in Appendix D. The Project Team also developed additional Excel files that were needed to support the output format creation.



Note. BLUFOR = blue forces; CSS = combat service support; OPFOR = opposing forces; PPT = Microsoft® PowerPoint®.

Figure 2. Measures development screen in Microsoft® Access.

Many of the output formats incorporate information that is either not readily available from or not tracked by the DCA. For example, a measure's pictorial output format might require a depiction of the unit's zone of action. The coordinates for the zone cannot be solely determined by obtaining the vertices of various graphical control measures plotted on the plan view display (PVD), due to a multiplicity of linear control measures, which may or may not be applicable to the current mission. On the other hand, an observer can readily determine which are the appropriate points to plot. Various reference data were also needed, such as the number of expected OPFOR and blue force (BLUFOR) weapon systems in the mission, maximum effective ranges of weapons, call signs for various staff members, weapon system categorization, and so forth.

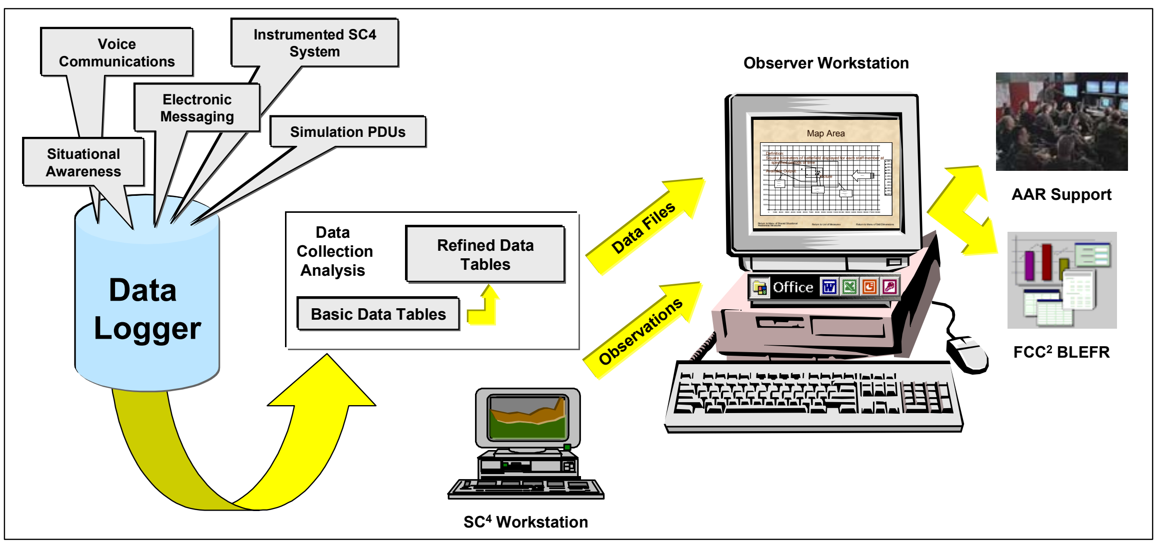
To simplify creating the output formats, a similar form to the one constructed in Microsoft® Access was developed in Microsoft® Excel so users could select the measure they wanted to create by clicking a button. When users click on the measure they want to create, another form appears with the various output formats available for that particular measure. A user could then choose a specific format or select all output formats. If only one output format is available for a measure, then the output is created immediately.

After the output format was developed, it was informally evaluated by SMEs who were not involved in the measures development process to better ensure that users would understand the outputs without further detailed explanation. Based on SME input, the Project Team refined the output formats by adding legends and changing colors until they were immediately interpretable.

If detailed explanations are required for users to understand the purpose of the picture, it will be of no value to exercise participants in an AAR (Meliza, 1996).

The next step was to provide a user-friendly medium through which this complex process could take place and where the final product could be either printed out or entered into a slide presentation to be used during an AAR, similar to an "AAR Presentation Manager" (Meliza, Bessemer, & Tan, 1994, p. 45). The Project Team decided that the best way to accomplish this goal was to develop a prototype Observer Workstation. The development process for the prototype is described next.

Observer Workstation. Figure 3 displays the entire measures development process and where an Observer Workstation would fit into the progression. The process starts with the information gathered in the MMBL by the data logger and processed through the DCA. These refined data combined with information inserted by observers provide the information needed by the Observer Workstation to create the measures automatically. Once the measures were developed through the Observer Workstation, they could be used during AARs as well as for any reports that required analysis of staff performance.



Note. AAR = after action review; BLEFR = Battle Lab Experiment Final Report; FCC2 = Future Combat Command and Control; PDU = protocol data unit; SC^4 = surrogate command, control, communications, and computers.

Figure 3. Automated measures development process.

Using the Microsoft® PowerPoint® presentation graphics program, a prototype graphical user interface (GUI) was built as a means for user-friendly measure output format creation. This GUI is what the user saw when interacting with the Observer Workstation. Sample screens can be seen in Figures 4 through 7.

Figure 4. Main menu of team process skill dimensions as seen in the graphical user interface.

Figure 5. Complete list of available automated measures as seen in the graphical user interface.

The goal for the Observer Workstation was that it would provide a user-friendly way for observers with no programming skills to produce meaningful output for feedback to the staff during AARs. When a user starts the program, an introductory screen appears. After entering the program, the user sees the instructions screen. The user can choose to read the instructions and then move on to the main menu, which contains a list of the skill dimensions (see Figure 4), or if familiar with the program and the available measures, the user can select to view the complete list of automated measures (see Figure 5).

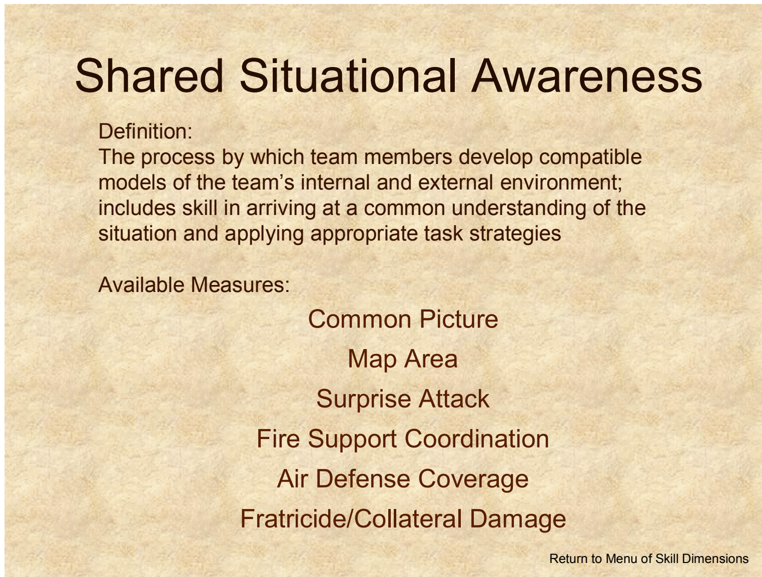


Figure 6. Definition and available measures for the shared situational awareness team process skill dimension as seen in the graphical user interface.

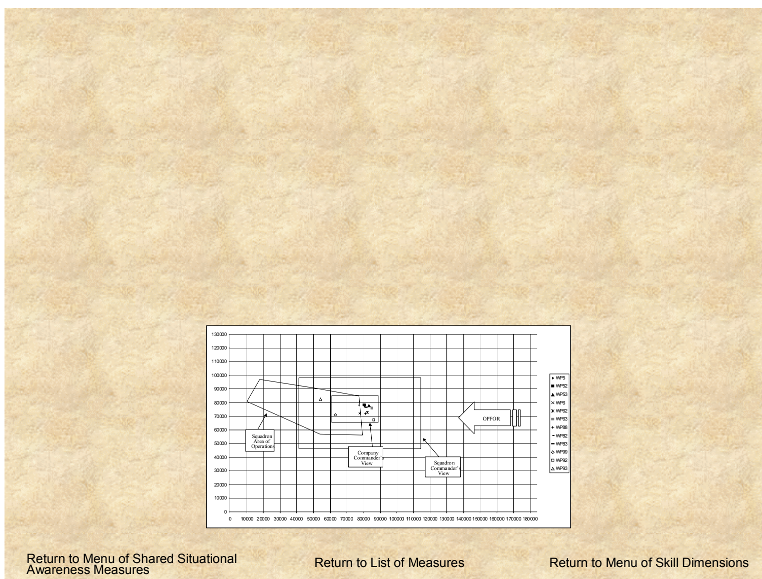


Figure 7. Definition and available output formats for the map area measure of shared situational awareness as seen in the graphical user interface.

If the user chooses the first option, the next screen will provide a list of the skill dimensions available for measurement. When the user selects one of the skill dimensions, the program goes to a screen that provides a definition of the skill dimension and all available measures for that dimension (see Figure 6). In the example shown in Figure 6, a definition is provided for the skill dimension, Shared Situational Awareness, along with the six available measures. When the user selects one of the measures, the program provides a definition of the measure selected as well as all available output formats for that particular measure. For example, as seen in Figure 7, the definition for Map Area is provided along with a sample of what the measure output will look like once it is developed. The Map Area measure can only be produced in picture format; however, some of the other measures have more than one format available and the user can click on the preferred format.

If the user chooses the complete list of available automated measures (see Figure 5), the program displays all 20 of the available measures in alphabetical order. When the user selects one of the measures, the program will go to that particular measure, as shown in Figure 7. The list of all available measures is a shortcut for those users who are already familiar with the measures and know which ones they want to develop.

Once the user selects a measure by clicking on it, Access automatically opens and the form seen in Figure 2 comes up. The user again selects the desired measure and the output for that measure is exported to Excel. From there, the user again selects the desired measure and its output format. The measure output is then created and saved as an Excel file.

The Observer Workstation is designed to be flexible and user-friendly. It allows the user to go almost anywhere within the program at any given time. For example, if the user selects the wrong skill dimension from the main menu, he or she can go back to the main menu and choose another skill dimension or go to the list of available measures. From the list of available measures screen, the user can choose to go to the main menu of skill dimensions. If the user selects a particular measure and decides not to develop it, he or she can go back to other measures within that skill dimension, the main menu of skill dimensions, or the list of all available measures.

Measures Implementation

The 20 developed automated measures along with the Observer Work Station (OWS) were implemented during the MMBL's FCC^2 experiment. The workstation was physically located in the data analysis area where the Project Team could readily coordinate with the MMBL programmers on FCC^2 DCA data file issues. It was also linked to the MMBL's intranet so that data files could be electronically downloaded. The Project Team had access to an SC^4 system where zones of action, OPFOR strengths, and other pertinent data could be extracted.

As the measures were tested during initial exercises, a number of changes had to be made. The biggest change required modifying the measures' software code to complete processing when a DCA source file unexpectedly did not contain any data. This condition, which did not occur in pre-implementation development testing, was a result of changes in unit organization and equipment that the Project Team had not anticipated prior to the start of the experiment. Processing of raw DCA data files for input to the OWS also took longer than expected. In the case of a full mission's data set, it took approximately 2 hours to produce the ASCII files needed for the measures. It then took another 30 to 45 minutes to import the data into Access hosted on the OWS. The net effect was that sample outputs from the measures were not available in time for use in AARs during the experiment. Some sample results were shared with MMBL personnel and contractors during the experiment to gain some informal feedback on formatting.

A full set of measure outputs was presented to the SAG for review and to the MMBL for Battle Lab Experiment Final Report (BLEFR) input after the FCC^2 experiment was concluded.

Results and Discussion

To provide trainers with a variety of means to depict staff performance, 33 output formats were designed to support the 20 automated measures. This section provides samples of each output format. The discussion of each output format is organized into three parts:

- A description is provided of what information is being presented along with any filters that were applied to the source database to obtain the data elements required to create the output. A rationale for the presenting the information is also provided.

- The measure's result is discussed briefly. The results should not be viewed as a reflection of the unit's performance. As described earlier in this report, the intent of the FCC^2 experimentation was to gain insights into future C^2 issues, not evaluate specific performance of a unit using conceptual weapons, organization, or doctrine. Performance standards for this type of unit have not been established.

- Comments on the utility of the output format and recommendations on how it could be improved are also provided.

Readers are further advised that the original output formats provided were developed with color and shape as primary identifying characteristics. Generally, blue squares are used to denote BLUFOR while red diamonds are used to denote OPFOR. Although the shapes are still identifiable, colors cannot be reproduced in this report. In the electronic versions of the output formats, the user can modify the characteristics or delete any data series to clarify the presentation of information. Again, this capability cannot be replicated in this report. Full color samples or electronic files of these measures and output formats can be obtained from the MMBL.

For the picture output formats, the Project Team created a grid system to represent the terrain database used during the trials. The terrain database covers an area 184 kilometers by 130 kilometers. The grid represents 10,000-meter intervals and covers the entire terrain. The Project Team has not yet integrated tactical ground maps into pictorial representations due to scaling problems and the potential for map information to clutter the presentation of critical information. The unit zone of action for each trial is also drawn automatically from data in a table created by an observer. The zone of action represents the geographical area where the majority of the unit's maneuver forces were positioned and where close combat with the OPFOR was expected. The pictorial representation of the unit zone of action along with an arrow indicating the OPFOR direction of movement has been found to adequately orient a training participant to the activity being depicted.

The sample results provided here are from Trial 1 during FCC^2. The results of all four FCC^2 trials were provided to the MMBL for use in the FCC^2 BLEFR. Results are categorized by the team process skill dimensions identified earlier. The mission of the unit, a reinforced battalion equivalent, was to defend against an attack by several OPFOR mechanized infantry brigades, reinforced with Corps-level artillery. The area to be defended is approximated by the unit zone of action, which is depicted on most of the pictures. Trial 1, which started at 0800 local time, lasted approximately 7 1/2 hours.

Adaptability

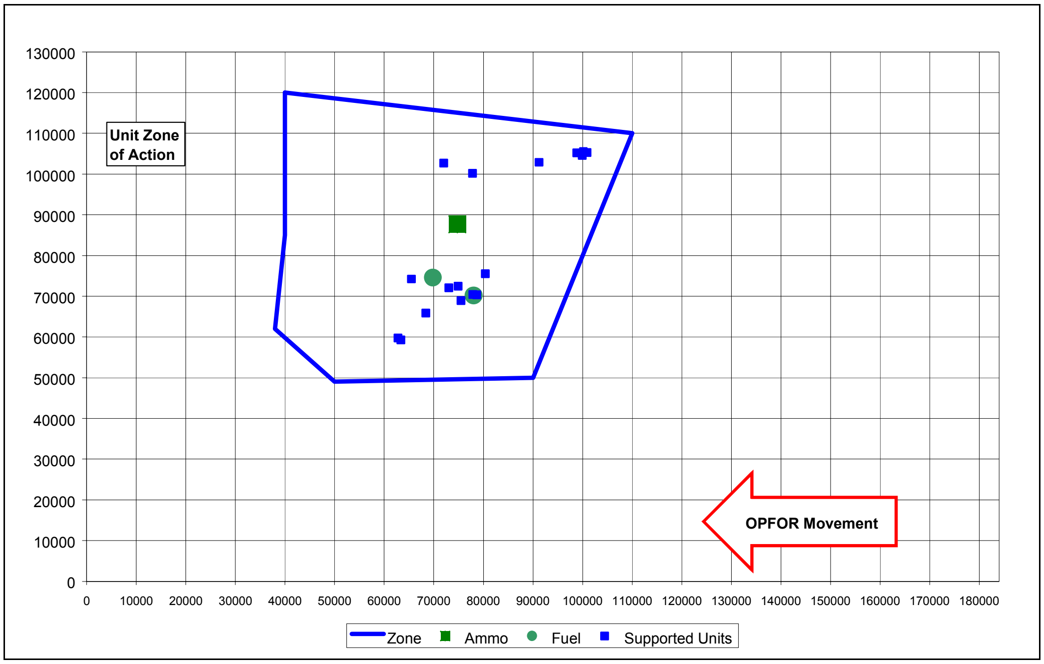
CSS Locations

The picture for this measure (Figure 8) was designed to show key vehicle locations relative to ammunition and fuel resupply vehicles. The platoon leader vehicle locations were used to represent the location of all major combat systems in the battalion. The Project Team decided that showing all of the vehicles would clutter the presentation. Normally, all of the vehicles within a maneuver platoon are located within visual range of each other, so the location of the platoon leader vehicle was thought to be an accurate representation of where the other vehicles were located. Also shown are the ammunition and fuel resupply vehicles. The Project Team used symbols for the resupply vehicles that were slightly larger than the platoon leader vehicle symbols to accentuate their location and to keep them from being covered by another vehicle type when they were plotted. Data for the vehicle locations were available at 5-minute intervals and come from the same source that would be used to show vehicle unit marking, type, and location on the unit member's PVD. There were a total of 10 ammunition carriers and 6 fuel carriers that could be depicted. Figure 8 depicts the locations of one ammunition and two fuel carriers.

The rationale for this measure was to identify if the staff's mission planning had incorporated sufficient flexibility to respond to unanticipated requirements, such as a platoon running out of fuel or ammunition during heavy combat or at a critical point in the mission. If the resupply vehicles were located where they were needed when they were needed, even from an unforeseen requirement, an inference could be made that the staff had adequately planned resupply.

At the time of this picture (approximately 1 hour after the trial started), there had been insufficient activity to determine if the ammunition and fuel resupply vehicles were adequately positioned to support the maneuver platoons. The fuel vehicles were in close proximity to the platoons, but the one ammunition vehicle depicted was at least 10,000 meters or about 15 minutes travel time from the nearest platoon.

The picture does provide a quick view of where the resupply vehicles are in relationship to the maneuver platoons within the unit. It does not provide the ammunition or fuel status for the subordinate units, which would indicate if the resupply vehicles are positioned appropriately. Adding subordinate unit supply indicators to the picture may improve its usefulness.



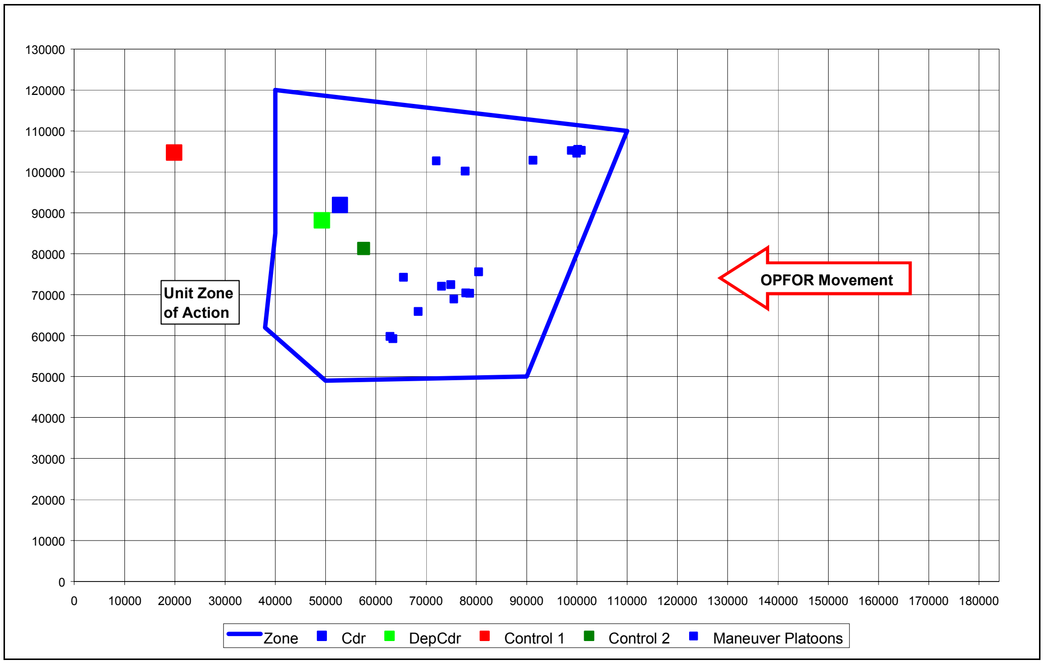
Note. OPFOR = opposing forces.

Figure 8. Combat service support locations at 0900.

Node Locations

The picture designed for this measure (see Figure 9) shows the location of the unit's commander and staff vehicles (nodes) in relationship to the location of vehicles of the maneuver platoon leaders, scout platoon leader, and platoon sergeant. The experimental staff in FCC^2, including the commander, comprised 14 officers and non-commissioned officers located in four vehicles. The commander had two assistant staff officers in his vehicle as did the deputy commander in his. The third staff vehicle (Control 1) was primarily concerned with controlling and monitoring the unit's indirect fires and engineer support. The fourth staff vehicle (Control 2) was responsible for monitoring the unit's logistical situation and controlling maintenance and resupply activities during FCC^2. The Project Team used symbols that were slightly larger than the platoon leader vehicles to denote the Control 1 and Control 2 vehicles. The Commander (Cdr) and Deputy Commander (DepCdr) vehicle designators were increased in size over the control vehicle symbols so that if the command vehicle were collocated with the control vehicles they could be differentiated. Data for the vehicle locations were available in 5-minute intervals and come from the same source that would be used to show vehicle unit marking, type, and location on the unit member's PVD.

The rationale for this measure was that the location of the unit's command and control nodes may indicate the ability of the staff to handle different requirements simultaneously while keeping positioned to maintain communications with all subordinate elements, and maintaining operational and physical security.



Note. OPFOR = opposing forces.

Figure 9. Node locations at 0900.

The locations of the nodes indicate that the Cdr and DepCdr nodes were centrally located in the zone of action and in close proximity to one another. Control 2 was likewise centrally located. Control 1 was located well outside of the zone of action. With the unit's SC^4 system capabilities, the ability to maintain communications was not dependent on proximity. Operational and physical security was a consideration, and ideally Control 1 should have been located closer to the unit's subordinate elements.

The picture provides a quick reference as to where the commander and staff were located at any point during the mission. If communications among staff vehicles and between the staff and subordinate units is affected by terrain or distance, then a communications pattern indicator similar to a range template might be useful. If physical security is a primary consideration, adding detected OPFOR locations might also be warranted.

Communication

Overlay Use

Table 4 shows which staff officers and team commanders had the same operational overlays available on their SC^4 system as did the unit commander. The source of the data is a record of each time the PVD Overlay Editor is used to create an overlay, or to display or turn off an existing overlay. The recorder also captures the time, the name of overlay file being manipulated, and the radio call sign of the soldier working with the overlay. For Trial 1, there were approximately 7,700 instances where the PVD Editor was used. Using the unit commander's radio call sign, the list was filtered several times, to identify the overlay files the commander used. That list was compared with the overlay files that the staff officers in his vehicle used, with other staff members' overlay files, and with his major subordinate team commander's overlay files.

The unit operations orders (OPORDs) were transmitted to the staff and subordinate units through the use of Whiteboard files and through the use of PVD overlay files. Use of the PVD overlay file that contains the OPORD operations overlay has been found by the Project Team, based on previous experimentation, to be a reliable indicator of who has received the OPORD. The comparison between the commander and his staff, and between the commander and his subordinate commanders may indicate whether there is a potential for miscommunication and a breakdown of situational awareness within the unit if the commanders and staff are not using the same overlays.

Table 4

Overlay Use

Cougar6 Overlays - Name	Command 1		Command 2		
	Cougar62	Cougar69	Cougar3	Cougar32	Cougar35
Defend Overlay 1		✓	✓		
Defend Overlay 2		✓	✓		
Defend Overlay 3		✓	✓		
Attack Overlay 1				✓	✓
Attack Overlay 2		✓			
Attack Overlay 3		✓			
Passage of Lines Overlay 1			✓	✓	✓
Passage of Lines Overlay 2			✓		
Unit Boundary Overlay					

Cougar6 Overlays - Name	Control 1			Control 2		
	Outlaw6	Outlaw2	Outlaw3	Head Hunter6	Head Hunter2	Head Hunter3
Defend Overlay 1	✓	✓	✓	✓	✓	✓
Defend Overlay 2	✓	✓	✓	✓		
Defend Overlay 3	✓	✓	✓	✓	✓	✓
Attack Overlay 1	✓					
Attack Overlay 2		✓	✓			
Attack Overlay 3						
Passage of Lines Overlay 1	✓	✓				
Passage of Lines Overlay 2	✓	✓				
Unit Boundary Overlay						

(table continues)

Table 4 (Continued)

Cougar6 Overlays - Name	Team Commanders			
	Eagle6	Fox6	Ghost6	Hawk6
Defend Overlay 1	✓	✓	✓	✓
Defend Overlay 2	✓	✓		✓
Defend Overlay 3	✓	✓	✓	✓
Attack Overlay 1	✓	✓		✓
Attack Overlay 2				
Attack Overlay 3	✓	✓		✓
Passage of Lines Overlay 1				
Passage of Lines Overlay 2				
Unit Boundary Overlay				

Among the staff, the senior officer in each node (Headhunter6 and Outlaw6) were also using the same overlay files as Cougar6 and Couger3, the Deputy Commander. Interestingly, only one of the commander's two assistants, Cougar69, had the same overlay files as he did. In the Command 2 node, only the Deputy Commander had overlay files related by title to the Defend mission of the unit. The team commanders (identified by the suffix "6" in the radio call sign), with the exception of Ghost6, had most of the same overlay files as the unit commander, Cougar6.

This measure identifies which members of the staff have the same overlay files as the unit commander. The Project Team had to construct these tables manually, since a reliable way to automatically match file names among the staff had not been developed by the time this report was prepared. By relying exclusively on file names as the basis for the comparison, there is a potential problem with identifying the right overlay. For example, if two staff members were working on the same overlay file simultaneously and closed the files to a common file server without changing or modifying the file name, the last-saved file would overwrite the first-saved file, even though the contents of the files might be different. The first staff officer would assume that his work on the overlay file had been saved when in fact it was not. Other staff officers might not even be aware that changes had been made to the overlay file and that they might not have the most current file. To counteract this possibility, the unit staff would have to establish a standing operating procedure (SOP) for naming OPORD overlays and tracking modifications to them.

Coordination

Damage to BLUFOR/OPFOR Systems

There are two bar graphs and two cumulative line graphs associated with this measure. The Project Team attempted to integrate BLUFOR and OPFOR data into single bar and line graphs, but the presentation of information was overly complex. The data used to create the output formats are the type of weapon system that was killed, the type of weapon system that killed it, and the time the weapon system was killed. The killed weapon system is classified into one of four groups through the use of a look-up table that is constructed ahead of the exercise by an observer on the OWS. The four groups are: "Air Defense" – weapon systems with a primary role of killing helicopters and other aircraft; “Artillery” – indirect fire weapon systems whose primary mission is to attack areas of OPFOR concentration throughout the depths of the battlefield; “IFV_APC” – ground combat vehicles whose primary mission is carry infantry soldiers and which may or may not have organic weapon systems capable of defeating tanks; and “Tank_FV” – tanks and other ground combat vehicles that have organic weapon systems capable of defeating tanks with direct fire, but whose primary mission is not to carry infantry soldiers. For those weapon systems, which did not fall into these four groupings, like attack helicopters or dismounted infantry, the designation “#N/A” is automatically assigned by Microsoft® Excel. Each weapon system is also classified as providing direct fire (line of sight) which means that the firing weapon system can see its target, or indirect fire (beyond line of sight or non-line of sight).

The rationale for this measure was two-fold. First, the staff is traditionally responsible for planning indirect fires in support of the commander’s concept of the operation. More indirect fire kills than direct fire kills may indicate that the staff has effectively coordinated fires. Also, the distribution of losses in the unit due to indirect fire and indirect fire from the OPFOR may indicate whether the staff was successful coordinating types of fire. Indirect weapon systems, due to their longer ranges, are habitually employed to attack the other side’s indirect fire weapon systems. Second, in the expected progression of a more conventional combat operation, the first weapon systems destroyed are those that are in close proximity or direct fire range. As the operation unfolds, artillery and air defense weapon systems, which are generally located farther away, are attacked later. If all classes of weapons are being attacked at the same time, the staff may be effectively coordinating fires throughout the battlefield.

In Figure 10, the data indicate that the majority of losses suffered by the OPFOR were due to indirect fire weapons. The only type of weapon system that experienced significant losses due to direct fire were Tank_FVs, which would be expected to be in the lead elements of an OPFOR attack. IFV_APCs also experienced losses due to direct fire, but not to the same extent that Tank_FVs were experiencing.

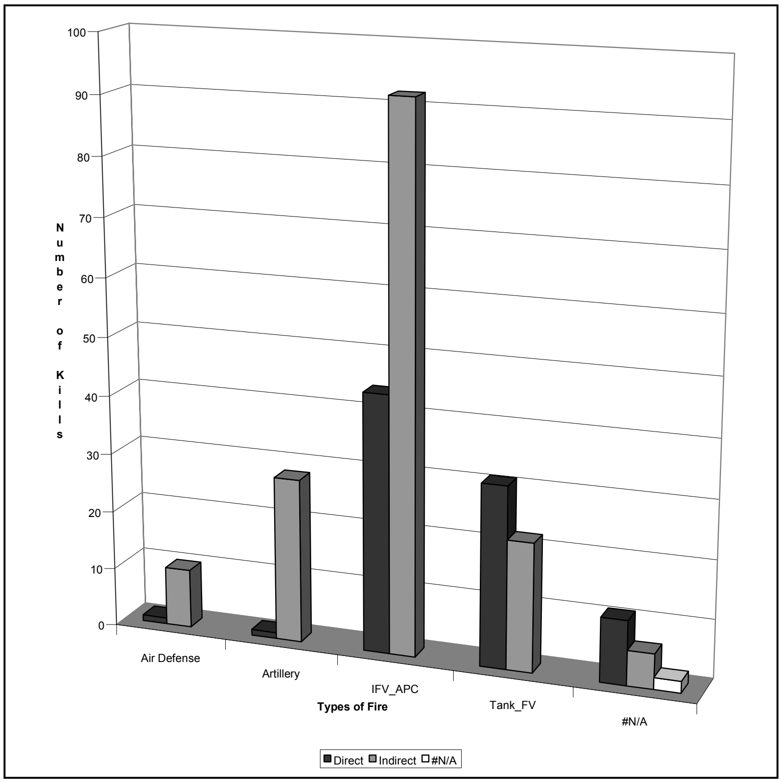


Figure 10. Opposing force damage from blue forces.

The BLUFOR Damage bar graph (Figure 11) also indicates that indirect fire was the primary cause of losses to the unit. More indirect fire systems were lost than direct fire systems, which may indicate that those systems were easier to target by the OPFOR because they moved less often, or that they were positioned too far forward, which increased their vulnerability. Further analysis would be required to find the reason for this result.

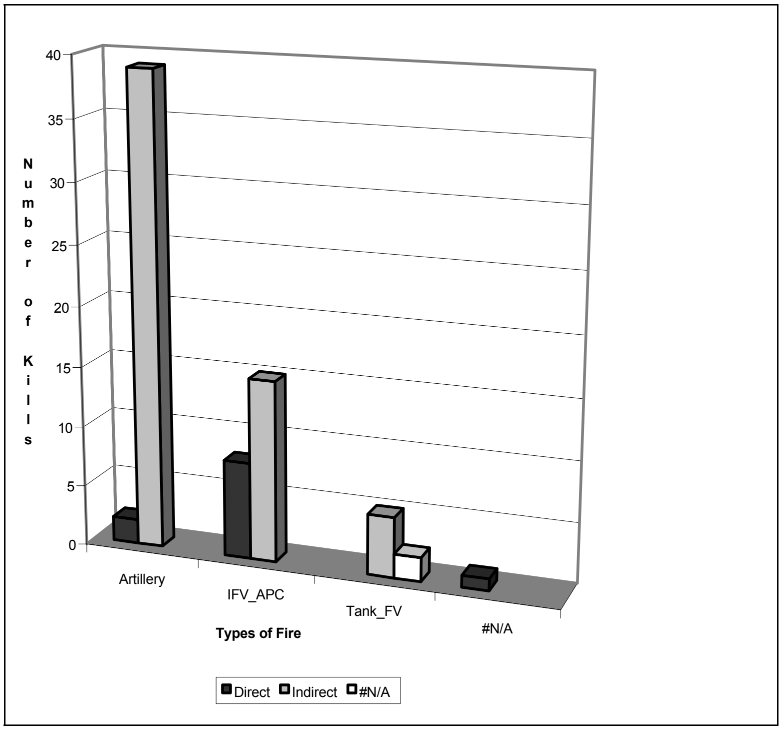


Figure 11. Blue force damage from opposing forces.

The OPFOR Destruction line graph (Figure 12) shows that Tank_FVs, IFV_APCs, and artillery systems were being destroyed early in the mission at approximately the same rate. This may indicate that the staff was able to coordinate fires throughout the depth of the battlefield. The drop in the rate of loss on Tank_FVs at the 2-hour mark, and the rate of loss for Artillery and Air Defense systems, starting around the 3-hour mark, may indicate that almost all of the OPFOR targets in these classes of weapons had been destroyed by that point in time, these systems were out of range, or were not being detected by the unit.

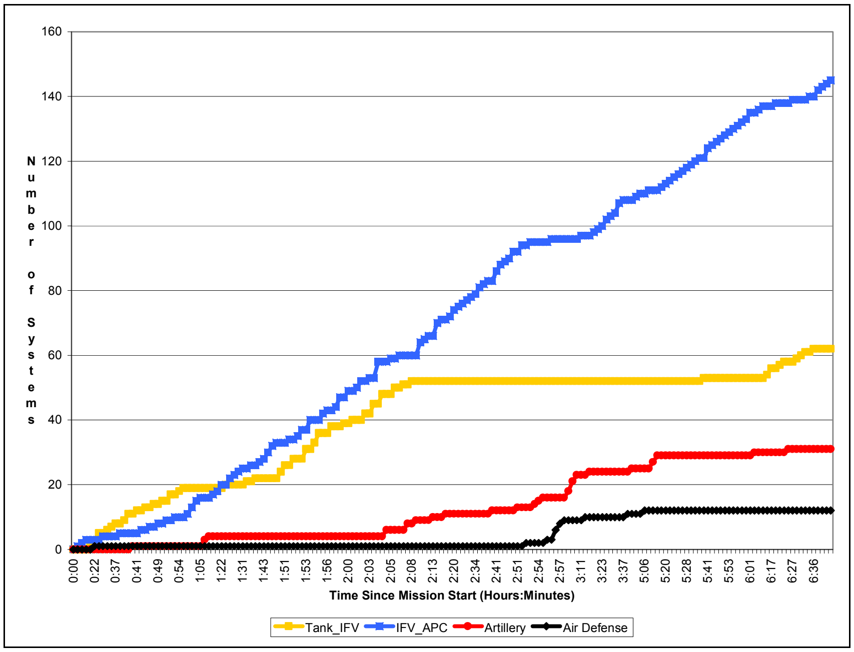


Figure 12. Opposing forces destruction by weapon classification over time.

The BLUFOR Destruction line graph (Figure 13) shows that the early rate of loss in the Artillery category carried throughout the trial. Additional analysis is required to explain this trend. The expected pattern would be that those elements of the unit that were closest to the OPFOR would sustain the most losses early in the fight. That does not appear to be the case in this trial.

Overall, the bar graphs appear more informative than the line graphs. The bar graphs show what types of weapons (direct or indirect) caused the most casualties. The line graphs, while showing at what time losses were occurring, would also require an observer to interpret why the losses were happening when they did. As they are currently constructed, the line graph could not stand alone, and this is an important goal for all of the measure output formats.

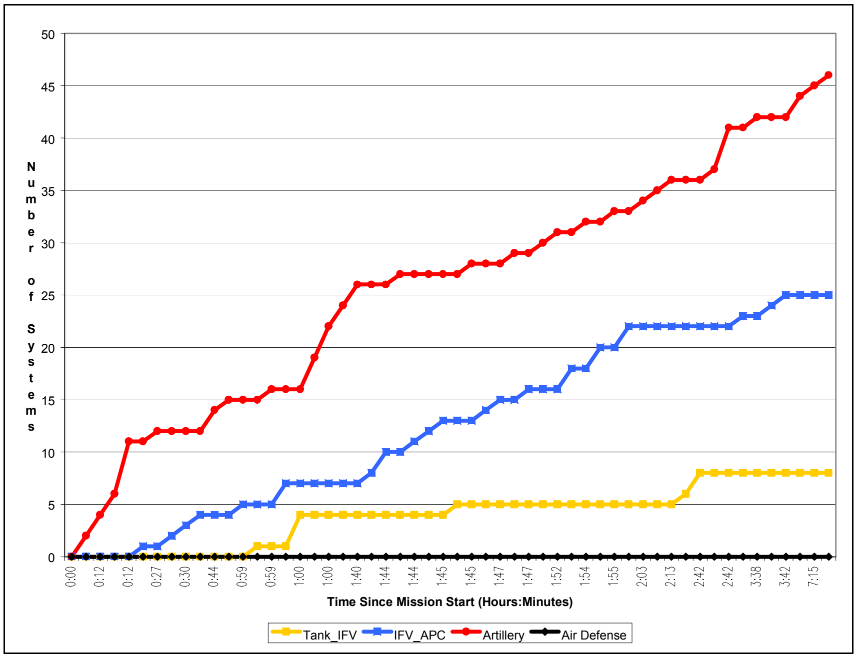


Figure 13. Blue force destruction by weapon classification over time.

Degradation of Forces

The graph developed for this measure (Figure 14) provides a comparison between the combat strength of both sides during the trial. At 5-minute intervals, the cumulative number of major combat systems that had been killed to that point is recorded. Those data are automatically integrated into a worksheet that has the number of systems with which each side started the mission. Losses are subtracted from the starting total and a percentage of the force that is still alive is then calculated. The data are then plotted along a timeline from when the mission began.

A rationale for this measure is that rapid destruction of the OPFOR reduces the risk of losses to the friendly unit. The rate of loss also may indicate battle tempo during the mission and whether the staff is coordinating the efforts of the unit to inflict the maximum number of losses in the shortest period of time.

Results from Trial 1 indicate that for the first 2 hours, the rates of loss between the OPFOR and friendly forces were comparable and moderate. After 2 hours, the rate of loss for the OPFOR substantially increased, while the rate of loss to the friendly side decreased considerably. Upward spikes in the lines for both sides indicate where either destroyed systems were replaced or additional forces were committed.

The graph provides a quick comparison of the strengths of the two sides over time. While it covers critical combat systems, it does not break the losses down into categories of combat systems as does the Damage to BLUFOR/OPFOR Systems measure output formats described earlier. A potential improvement might be to add lines to indicate when the units move from green to amber to red to black.

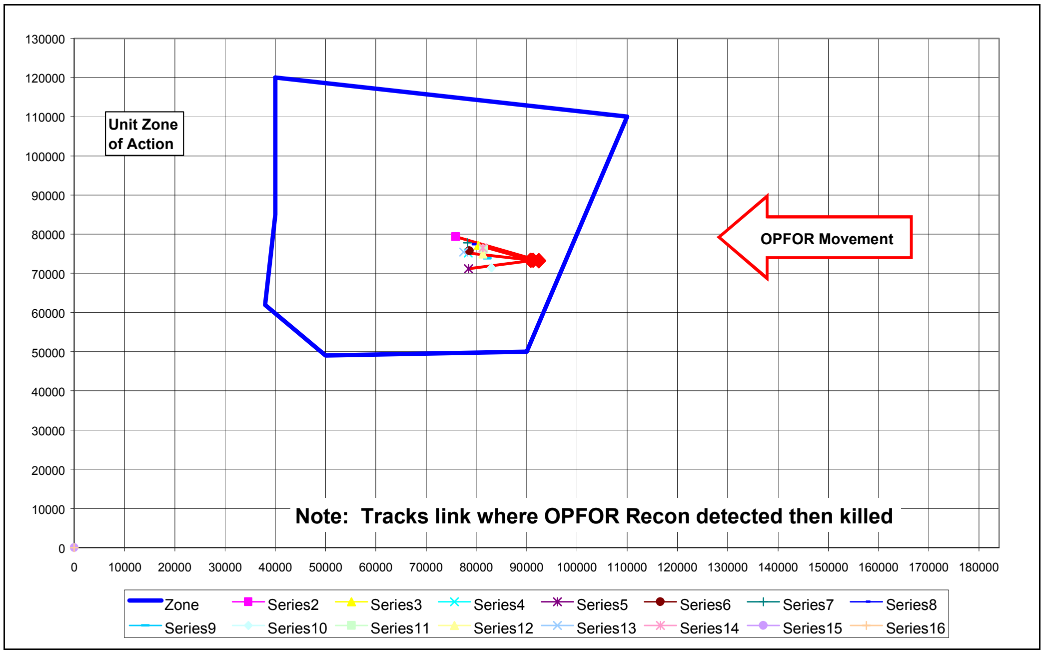
Figure 14. Degradation of forces over time.

Counterreconnaissance Effectiveness

The picture developed for this measure (Figure 15) reflects the location where OPFOR ground reconnaissance vehicles were first detected and the location where they were killed. In order to visually link these two points a straight line is plotted between them; the line does not reflect the actual route the reconnaissance vehicle was following before it was killed. The legend for this picture identifies the pairing of the location where the vehicle was detected and the location where it was killed as a "Series." This identification is assigned automatically. While the legend could have been excluded, the number of the series could be used to identify how vehicles were being tracked, especially in those instances where lines or vehicle locations are being superimposed on one another. In this case, eight vehicles were being tracked (the number of series divided by two).

This measure may indicate if the staff was coordinating fires effectively to negate the OPFOR ground reconnaissance effort. If the OPFOR cannot detect the unit, the unit reduces its vulnerability. The OPFOR ground reconnaissance vehicles are high priority, high payoff targets (HPTs) that, doctrinally, should be among the first targets attacked after they have been detected.

The data presented suggest that OPFOR ground reconnaissance vehicles, while detected soon after they had moved into the unit's zone of action, were not killed until they had an opportunity to move, on average, about 10,000 meters farther into the zone. What is not available in this output format is the time that the OPFOR vehicles were detected and subsequently killed. Those data would indicate how much time the OPFOR would have had to detect the unit. Also missing are unit positions, which again would provide an indication of how much information the OPFOR could have gained before they were destroyed.



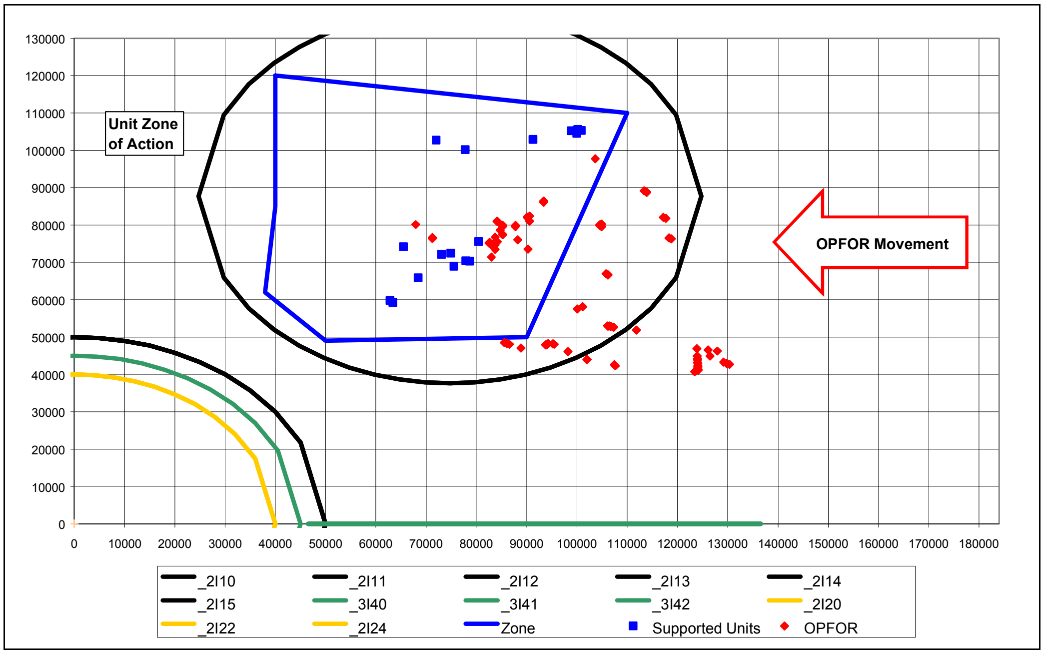
Note. OPFOR = opposing forces.

Figure 15. Counterreconnaissance effectiveness.

Artillery and Counterfire Radar Coverage

The picture designed for this measure (Figure 16) depicts the range templates of the indirect fire weapons that are controlled by the unit staff. There are a total of 12 systems – six missiles, three rockets, and three 155mm howitzers that could be positioned by the staff. Location for individual systems was available at 5-minute intervals. To create the range templates, data for each individual weapon system are automatically posted to a worksheet, which plots the points necessary to create the circle representing the range template. If a particular system has been destroyed, the location of the system is calculated as being at 0,0 and the range template for it is drawn around that point, as indicated in the lower left portion of Figure 16. The legend provides the unit identification number for the individual systems. Units being supported by the weapon systems are depicted by plotting the maneuver platoon leader positions. The OPFOR depicted represent detected OPFOR systems. The OPFOR location data were available at 20-minute intervals.

This measure is designed to provide information on whether the staff is effectively coordinating the indirect fire assets it directly controls to support both its subordinate units and the commander's intent and concept of the operation. Typically, indirect fire weapon systems, while geographically dispersed, are positioned where they can mass timely fires at decisive points in the operation, and attack targets of opportunity while reducing BLUFOR exposure to OPFOR counterartillery fires.



Note. OPFOR = opposing forces.

Figure 16. Artillery coverage.

The results depicted in Figure 16 show that the missile systems are positioned to engage targets throughout the unit's zone of action and most of the detected OPFOR targets outside of the zone. Several of the unit's weapon systems are shown as being destroyed or not available (lower left portion of Figure 16). This may be explained by the loss of these systems to OPFOR indirect fire, which was noted under the results obtained by the Damage to BLUFOR/OPFOR Systems measure.

The output format provides a clear depiction of what targets could be engaged by the weapon systems. The legend needs to be simplified to relate the color of the range template to the type of weapon systems being represented rather than the unit vehicle marking number. Another improvement would be to automatically remove individual weapon systems that were destroyed or not available from the graph which would prevent their range templates from being plotted around the 0,0 point and remove their unit vehicle marking number from the legend.

Kill Distance

There are two output formats for this measure – a line graph and a table. The line graph (Figure 17) is generated by categorizing the range from the shooter to the target for each OPFOR weapon systems killed. To facilitate the presentation of information, 12 range categories were created. Initially, the line graph was designed to report information for those weapon systems that were directly controlled by the staff (missile, rocket, and 155mm howitzer). Since the number of kills for those systems was limited during the experiment, three additional weapon systems were added (indirect fire [IDF_GUN], mortar [MTR], and precision attack missile

[PAM]). The number of kills by the various weapon systems for each range category was then computed and plotted. A linear trendline was then created for each weapon system. As seen in Figure 17, just three weapon systems accounted for all of the Trial 1 kills, and just two systems had a sufficient number of kills to generate a trendline. All of the mortar systems (vehicle robot mortar [VEH_ROB_MTR]) kills occurred in the same range category, which did not generate a discernible trend line in the graph.

The rationale for this output format was that if the staff was effectively coordinating the fires of the weapons it directly controlled, then the majority of the kills they obtained should be nearer the maximum effective range of the weapon rather than the minimum effective range of the weapon.

The results obtained by this measure indicate that the unit was not maximizing the effectiveness of the IDF_GUN weapon systems; no clear trend is discernible for the PAM weapon systems. Both of these weapon systems were controlled by the unit's subordinate teams. If all of the weapon systems in the unit had been plotted, the graph might have been too crowded.

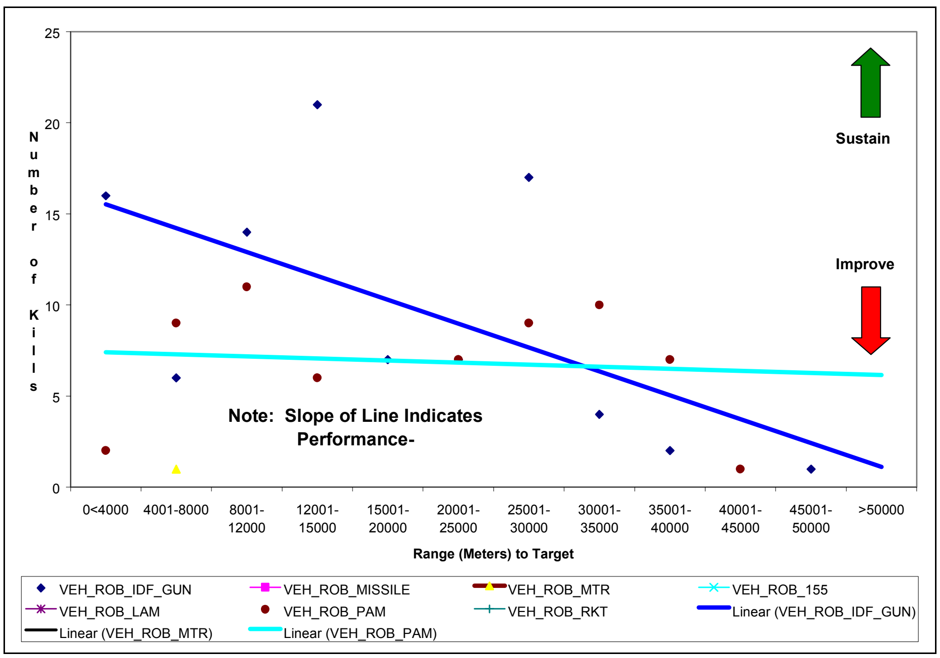


Figure 17. Kill distance (squadron controlled weapons) graph.

Figure 18 is the other output format available for this measure. The average engagement range for each weapon system is automatically inserted into the table. To provide a comparison with OPFOR performance, the data for their weapon systems are also provided. Data for all weapon systems involved in Trial 1 are reflected in this table. While this table provides the maximum effective ranges for weapon systems which are not provided in the graph, one or two engagements at very long ranges could skew the results somewhat. The graph provides data that indicate how the engagements were distributed across the effective range of each system.

The data in the table confirm the data interpretation of the graph; that is, the IDF_GUN system was not being employed at ranges commensurate with its capabilities, while the PAM system average kill distance was mid-point in its effectiveness range.

BLUFOR

Weapon System	Maximum Effective Range	Average Range
Indirect		
VEH_ROB_IDF_GUN	50000	15526
VEH_ROB_PAM	50000	20827
VEH_ROB_LAM	50000	#N/A
VEH_ROB_IDF_RKT	50000	#N/A
VEH_ROB_155	27300	#N/A
VEH_ROB_MTR	50000	6012
Direct		
VEH_ROB_IDF_GUN(KE)	50000	#N/A
VEH_MAND_TRP_TRANS	2000	1818
VEH MAND TRP TRANS CM	2000	979
VEH_MAND_C2	1000	#N/A

OPFOR

Weapon System	Maximum Effective Range	Average Range
Indirect		
ELDO VEH 2S19	24700	#N/A
ELDO VEH 2S23	24700	#N/A
ELDO_VEH_2S9	5000	#N/A
ELDO_VEH_BM_21	20300	#N/A
ELDO_VEH_BM_22	140000	30253
Direct		
ELDO_VEH_BMP_3	4000	#N/A
ELDO_VEH_BRDM_2	2000	#N/A
ELDO_VEH_BRM_3	4000	2059
ELDO_VEH_BTR_80	4000	#N/A
ELDO_VEH_BTR_90	1000	252
ELDO_VEH_T72_MP	1000	2104
ELDO_VEH_T80_UD	1000	#N/A
ELDO_VEH_T90	1000	2436

Note. BLUFOR = blue forces; OPFOR = opposing forces.

Figure 18. Kill distance table.

Improvements to the output formats for this measure might include providing an indicator of the maximum effective range for the particular weapon system being plotted on the graph. Including the number of kills for each weapon system in the table would inform the reader of the sample size and give more power to the results, especially if the sample size is large.

Sensor-Shooter Time Lag

There are two output formats associated with this measure – a graph and a picture. The graph (Figure 19) is created from data that provide the time the target was spotted and the time it was killed. The difference between the two times is then graphed, based on seven 30-minute time categories. The 30-minute categories are based on the Project Team's previous experience with experiments similar to FCC^2, where the preponderance of targets was killed within 180 minutes of being detected. This measure is used as an indicator of the effectiveness of the staff in coordinating the fire engagements of the unit. Unless the unit is being constrained by external factors, such as when the OPFOR has been detected massing along an international border but hostilities have not yet broken out or when ammunition supplies are limited, the shorter the difference in time between when a target is detected and then subsequently killed, the better the staff may be in coordinating fires.

The Trial 1 data indicate that the unit was able to kill the majority of OPFOR targets within 120 minutes of the time they were detected. During FCC^2, resupply rates for key ammunition types were constrained which may explain why very few targets were killed within 30 minutes of detection or many targets were killed more than 180 minutes after they were detected. Results from additional trials would be needed to establish a baseline to determine if the performance indicated by this trial should be sustained or improved upon.

The picture (Figure 20) is derived from plotting the location of the OPFOR target when it was detected and the location of where it was killed. The lines on the picture simply link the two points and do not indicate the route that the target took before it was killed. The unit's zone of action is also plotted from a table created by an observer. An arrow is used to indicate the OPFOR general direction of movement. Figure 20 complements the data presented in Figure 19. Based on ground tactical movement speeds of 25 kilometers per hour using highways, the clustering of dead vehicle symbols in the center of the zone of action indicate that the majority of vehicles did not move between the time they were detected and the time they were attacked. Vehicles that were detected outside of unit's zone of action were able to travel greater distances before they were killed, which would result in an increase in the sensor-shooter lag time for those engagements.

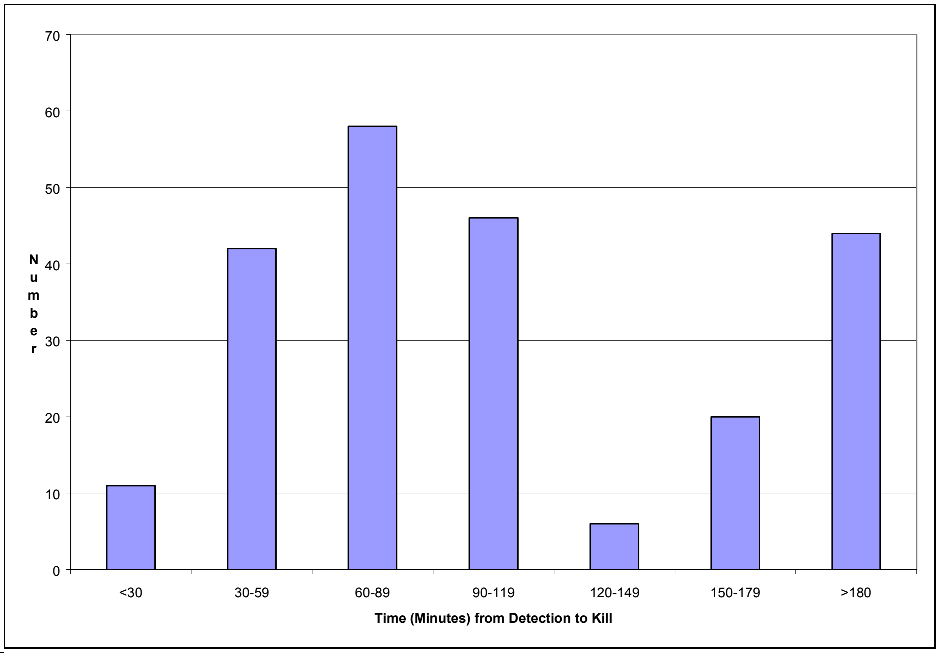
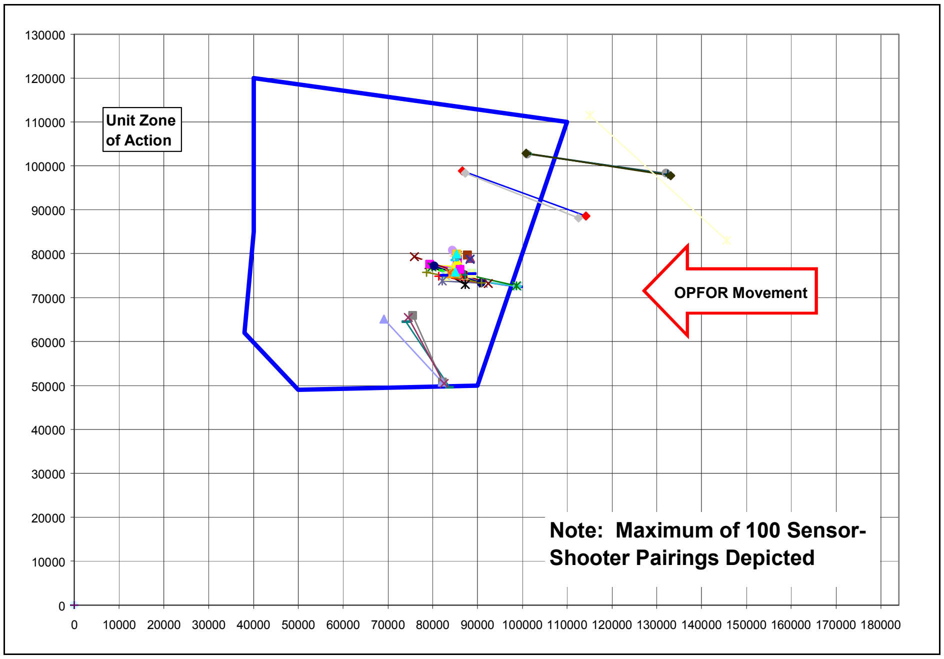


Figure 19. Sensor-shooter time lag graph.



Note. OPFOR = opposing forces.

Figure 20. Sensor-shooter time lag picture.

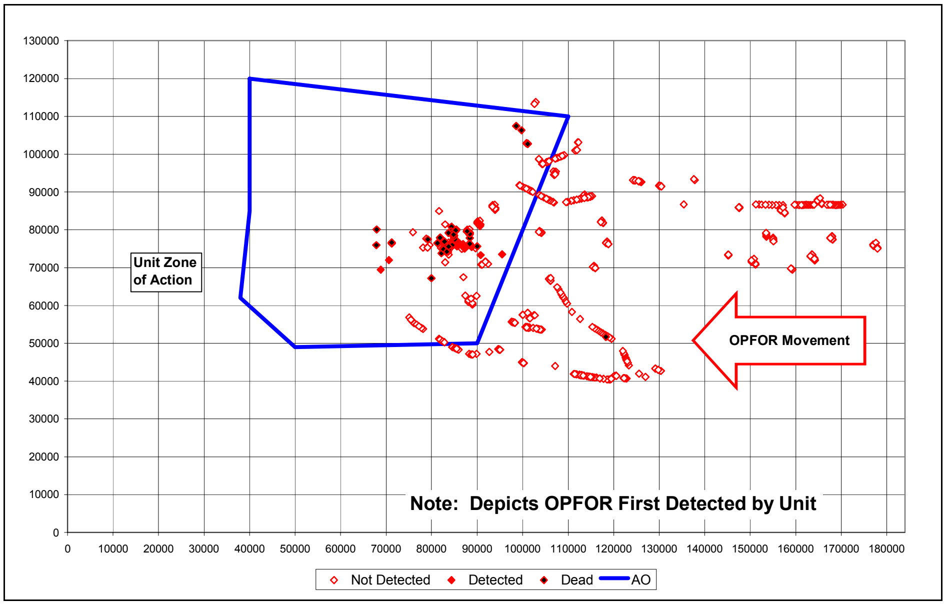
There are several potential improvements that could be made to the output formats. If objective standards have been established for the time lag between when sensors have detected a target and the time it was killed, the bars outside of the tolerance could be given a different color or pattern to distinguish how much unit needs to sustain or improve its targeting performance.

Time of detection and time of kill could be added to the picture to give a representation of the time lag for individual targets. This would be most beneficial for a few critical targets since providing that information for all targets would clutter the presentation, particularly where there are large numbers of vehicles clustered.

Decision-Making

Sensor Coverage

Figure 21 provides information about the effectiveness of the various sensors that were controlled by the unit's staff during Trial 1. The OPFOR data come from two sources. The locations for OPFOR systems that are identified as "Not Detected" are derived simulation PDUs. These locations are available at 5-minute intervals. The locations for systems that have been identified as "Detected" are provided by data that record the location and time at which the OPFOR vehicle is under observation and the identification of the unit or vehicle that is observing it. The data have been filtered so that only those OPFOR vehicles that were first detected by and are currently being observed by the unit are displayed. These data are available in 20-minute intervals. The detected OPFOR vehicle data are filtered again to identify those vehicles that have a "killed" status at the time they are being observed. In creating the picture, the "Not Detected" systems are plotted first with an outlined diamond symbol. The "Detected" vehicles are plotted next in a red diamond symbol. The detected vehicle symbol will be superimposed over the "Not Detected" symbol. The "Dead" symbol is a black diamond which is then superimposed over the detected symbol. The unit zone of action is then plotted from a table created by an observer and an arrow indicating the general direction of OPFOR movement is added.



Note. AO = area of operations; OPFOR = opposing forces.

Figure 21. Sensor coverage at 0920.

The rationale for this measure is based on the capability of the SC^4 system, which allows the unit commander to visualize the entire "sensed" battlefield on his PVD. The information that is being displayed on the PVD comes from a wide variety of sources, but the sensors that are being controlled by the staff provide a majority of the OPFOR information. If the staff is not properly deploying and monitoring performance of their sensors, then the information that is being displayed to the commander will be incomplete, which will prevent him from making a decision using all information that could be made available to him.

The results depicted in Figure 21 indicate that 50 minutes into the exercise, a considerable number of the OPFOR systems that were participating in the trial had not yet been detected. However, most of those systems that had been detected within the zone of action were killed.

Depending on the number of OPFOR systems that have been detected and killed, the picture could evolve into a complex presentation of information. One way to simplify the presentation of information may be to create two different pictures. One picture would present the "Not Detected" and "Detected" OPFOR system locations, while a second picture would present the "Detected" and "Dead" vehicle locations.

Multiple Fire Engagements

Table 5 lists the three OPFOR weapon systems that were attacked after they were reported as being killed. Battle damage assessment information is automatically posted as the SC^4 system is updated every 30 seconds. With this information available to everyone in the unit, instances where the target is fired upon after it is destroyed should be infrequent. The table provides information on the target and the unit systems that participated in the multiple engagements. One of the critical pieces of information is the time that the second attack took place. It would be possible for an OPFOR system to be targeted by two different weapon systems during the short period in which the results of the initial engagement had not yet disseminated.

Table 5

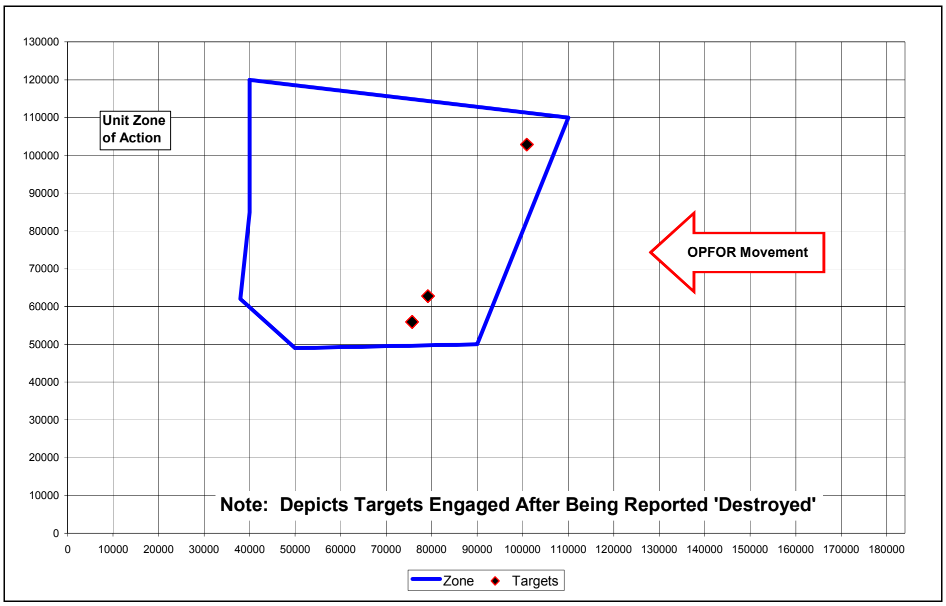
Multiple Fire Engagements Against Targets Previously Reported as Destroyed

Target Mark	Target Type	Firer Mark	Firer Type	Ammo	Effect	Time
_101A12	ELDO_VEH_BTR_90	_2E10	VEH_MAND_TRP_TRANS_CMD	German_35AP	KL	9:02
_101A12	ELDO_VEH_BTR_90	_2G410P	VEH_ROB_PAM	PAM	KL	10:46
_119H13	ELDO_VEH_2S_23	_2F38P	VEH_ROB_PAM	PAM		10:53
_119H13	ELDO_VEH_2S_23	_2F19P	VEH_ROB_PAM	PAM	KL	13:18
_119H23	ELDO_VEH_2S_23	_2F38P	VEH_ROB_PAM	PAM	KL	10:54
_119H23	ELDO_VEH_2S_23	_2F33R	VEH_ROB_IDF_GUN	MRAAS_MPERM	KL	11:08

Figure 22 complements the data presented in Table 5 by depicting the locations at which the three multiple fire engagements took place. This information may be of use in analyzing why a particular target was engaged more than once.

Based on the approximately 225 OPFOR weapon systems that were engaged and killed during the trial (Figure 11), only three OPFOR systems were subsequently attacked again after they had been killed. This result may indicate that the unit was closely tracking OPFOR battle damage and had a high degree of confidence that the SC^4 system was providing them with accurate information.

The picture output format may provide more information if the location of the shooters are also displayed. Adding the locations of other OPFOR weapon systems that were near the targeted systems at the time they were attacked again may also provide additional context for analyzing the engagements. Incorporating the table into the picture would also facilitate analysis.



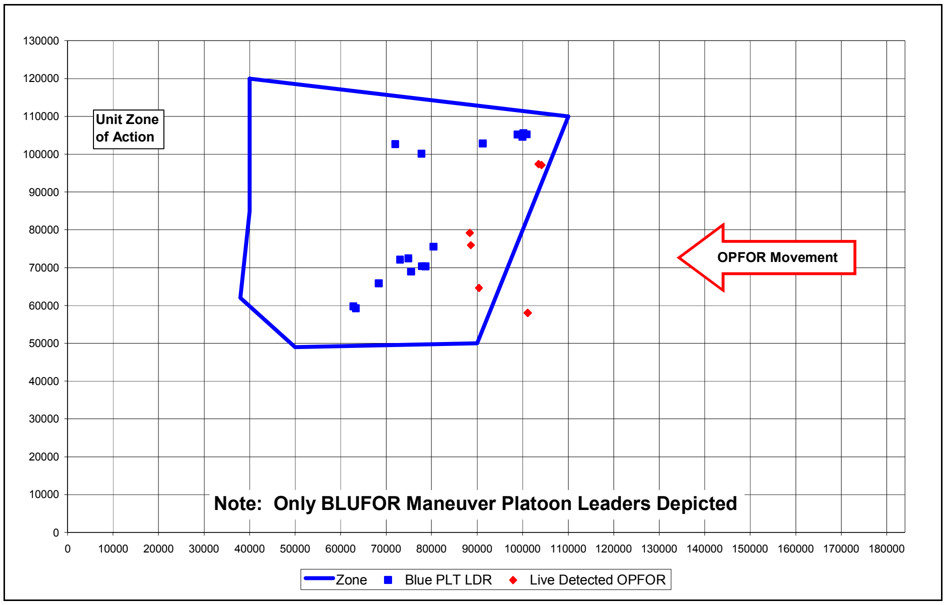
Note. OPFOR = opposing forces.

Figure 22. Multiple fire engagements.

Maneuver Battle Sets

Figure 23 depicts the location of the unit's maneuver platoon leader vehicles in relation to detected OPFOR weapon systems. The unit vehicle location data are available at 5-minute intervals. The OPFOR location data are available in 20-minute intervals. The Project Team had originally designed this measure to plot the locations of like sets: BLUFOR platoon leader vehicles against OPFOR platoon leader vehicles. However, since the OPFOR locations are based on whether they had been detected or not, relying on just detected OPFOR platoon leader vehicles would not provide sufficient reliable information about the OPFOR to indicate whether the unit had positioned its subordinate units appropriately. Consequently, the Project Team decided to plot the locations of all detected OPFOR weapon systems, rather than just detected OPFOR platoon leader vehicles.

The rationale for this measure was to provide an indicator of whether the staff estimates and other information staff members provided to the commander allowed him to make the right decision on positioning his maneuver forces prior to the start of the trial. Based on the early information presented in Figure 23, it appears that the unit's subordinate maneuver platoons were positioned to block the detected OPFOR vehicles.



Note. BLUFOR = blue forces; OPFOR = opposing forces.

Figure 23. Maneuver Battle Sets at 0900.

The picture format for this measure could be improved by changing the symbols from vehicles to reflect standard Army symbols and labels for friendly forces and the OPFOR and increasing their size somewhat. It would also be helpful to be able to automatically depict OPFOR units that are expected to be committed against the unit, but have not yet been detected or identified.

CSS Available Over Time

Figure 24 depicts the number of rounds available for four critical types of ammunition over the course of Trial 1. The intent of this measure was to determine if the staff had adequately planned to ensure that the unit would not run out of ammunition or fuel during a critical phase of the operation. Since fuel was not a major factor in the outcome of any trial during FCC^2, the Project Team focused on ammunition as an indicator of the staff's effectiveness in logistical planning to support the commander's intent. The results indicate that with the exception of a 40-minute period, starting at 2 hours into the mission, the number of rounds available in the unit was fairly constant and by the end of the mission was very close to what they had available at the start.

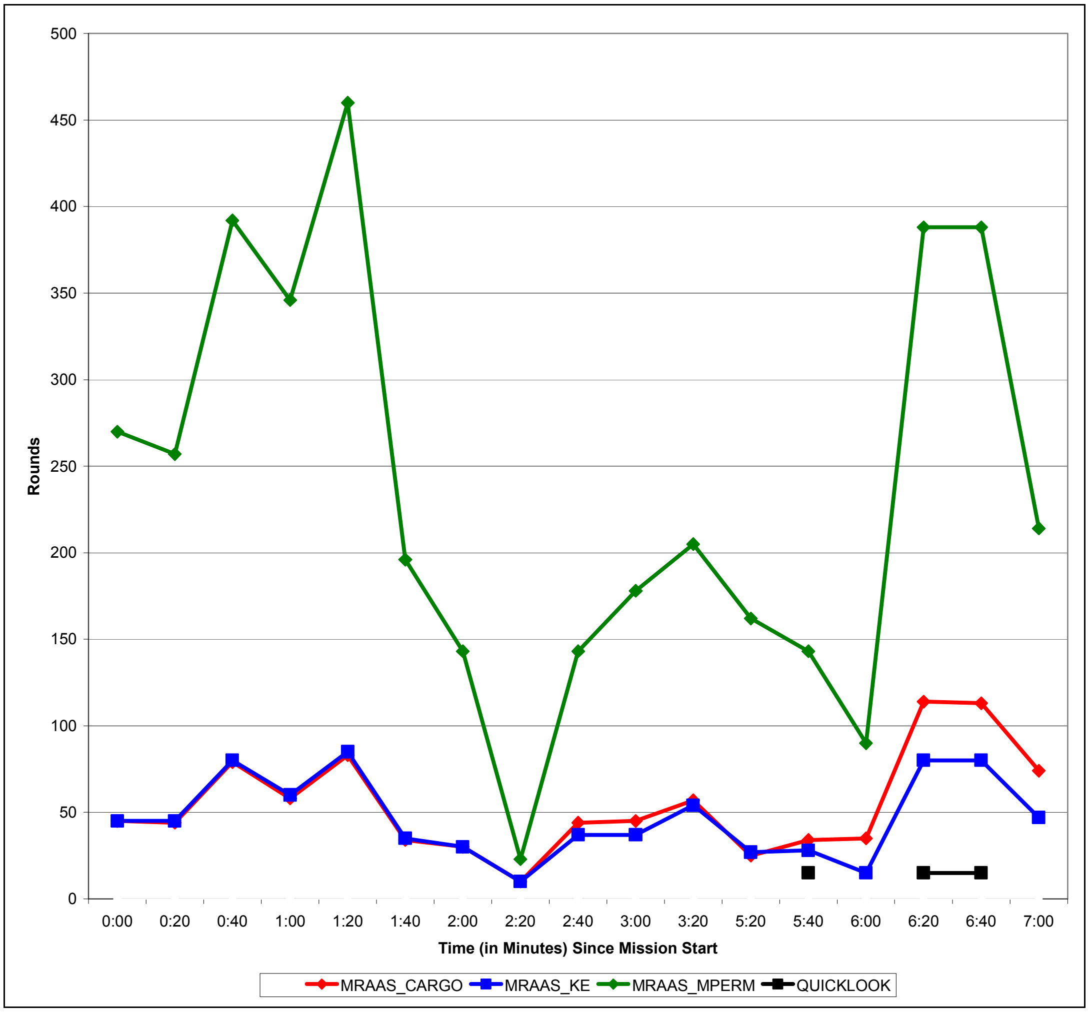


Figure 24. Ammunition available over time.

While consideration was given to trying to add a line to indicate what the minimum desired stockage level, or unit basic load, was for these types of ammunition, the Project Team was unable to automatically generate a line or other device compatible with the rest of the data that would provide that information. Such information would be useful in determining whether the staff needed to sustain or improve its performance in this area. Changing the format to graph the percentage of the unit basic load for each type of ammunition being tracked that is available over time would be a technique for overcoming the limitation of the current output format. Visibility on the number of rounds would be lost, however. In some instances such as when the unit is cross-leveling ammunition, the actual number of rounds available would be an important management tool. Further research is required to determine the optimal format for this measure.

Performance Monitoring and Feedback

Effects of Targeting

Three output formats were developed by the Project Team for this measure: a table, a picture, and a line graph. In the table, the categorization of HPT and the number of expected targets for each category is manually entered into the table prior to the start of the trial by an observer. The number of expected targets reflects an intelligence estimate by the unit's higher headquarters of OPFOR weapon systems that could be committed in the unit's zone of action. The targeted number is generated automatically by categorizing the targets that the experimental unit engaged and then counting the number in each category. The number of targets engaged could be higher than the number expected if the number of OPFOR participating in the trial is increased or if the unit engages targets outside its zone of action. The picture depicts the location of where each OPFOR vehicle or weapon system was killed. The line graph provides information similar to the Damage to BLUFOR/OPFOR Systems measure discussed earlier. The major difference is that the Damage measure begins counting the damage from a zero point while this measure starts with the expected number and counts down. Another difference is that the Damage measure provides the data in percentages, while numbers are used for this measure.

The rationale for this measure is that destruction of HVTs/HPTs by the weapon systems that are under the control of the experimental unit's staff may be an indicator of the staff's ability to effectively monitor their unit's performance against the desired result and to provide necessary feedback to the commander or guidance to subordinate units to get back on track.

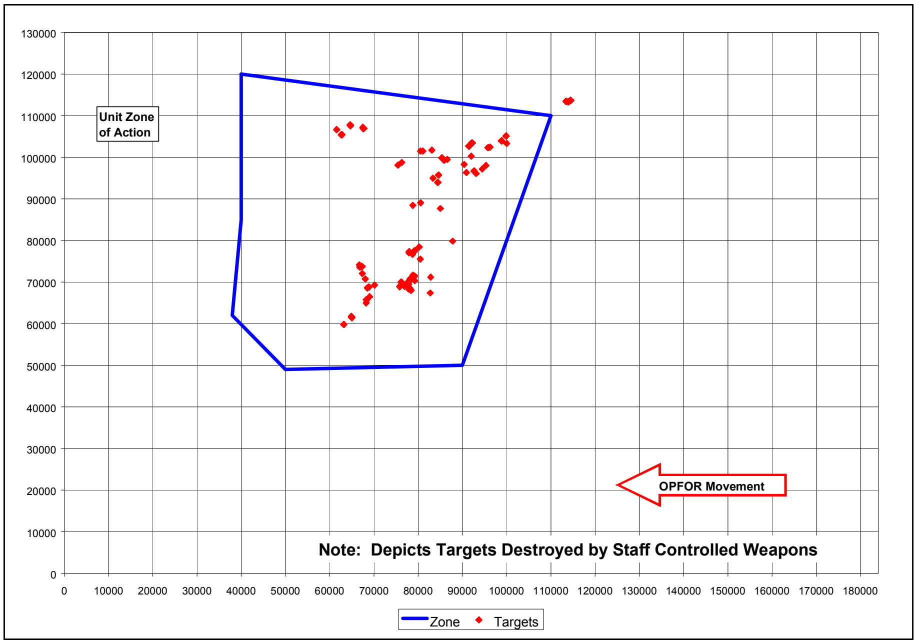
The results for the measure provided in Table 6 indicate that the number of Tank_FVs and Air Defense systems targeted were somewhat greater than the number expected. This difference can be seen in the picture (Figure 25) which depicts the location of the targets that were destroyed. Several targets are located outside of the unit's zone of action, which may explain why the number of Tank_FVs targeted exceeded the expected number.

Table 6

Effects of Targeting

High Payoff Target	Expected	Targeted
Tank_FV	40	53
IFV_APC	153	132
Artillery	90	20
Air Defense	17	22

Note. FV = fighting vehicle; IFV_APC = infantry fighting vehicle/armored personnel carrier.



Note. OPFOR = opposing forces.

Figure 25. Effects of targeting.

The results from the line graph (Figure 26) indicate that the unit was able to target and destroy in a short period of time almost all of the HVT/HPT except for artillery systems. The effects of this targeting effort can be also be seen in the results of from the Damage Measure (Figure 11) where it shows that the unit suffered significant losses from OPFOR artillery systems with minimum losses from other types of OPFOR weapon systems.

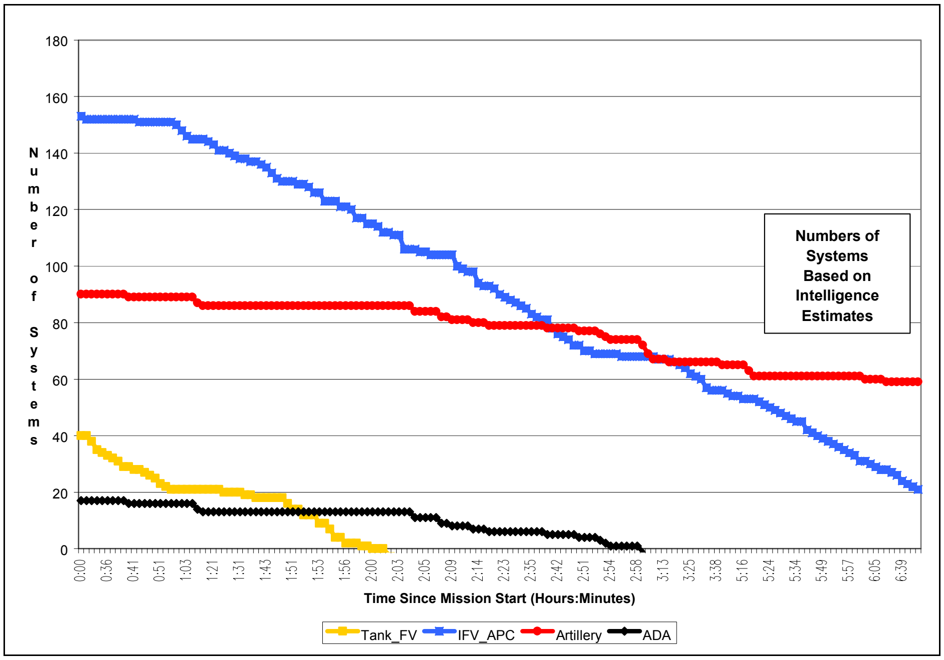


Figure 26. Effect of targeting opposing force high value targets over time.

The table format could be improved by breaking down the categories of high pay targets into individual weapon system types. This might help the staff look to sustain or sustain their targeting efforts against particular systems, not just against categories of weapons. Also, the killed symbols on the picture could be coded by color or pattern to reflect the categorization of weapon systems.

Shared Situational Awareness

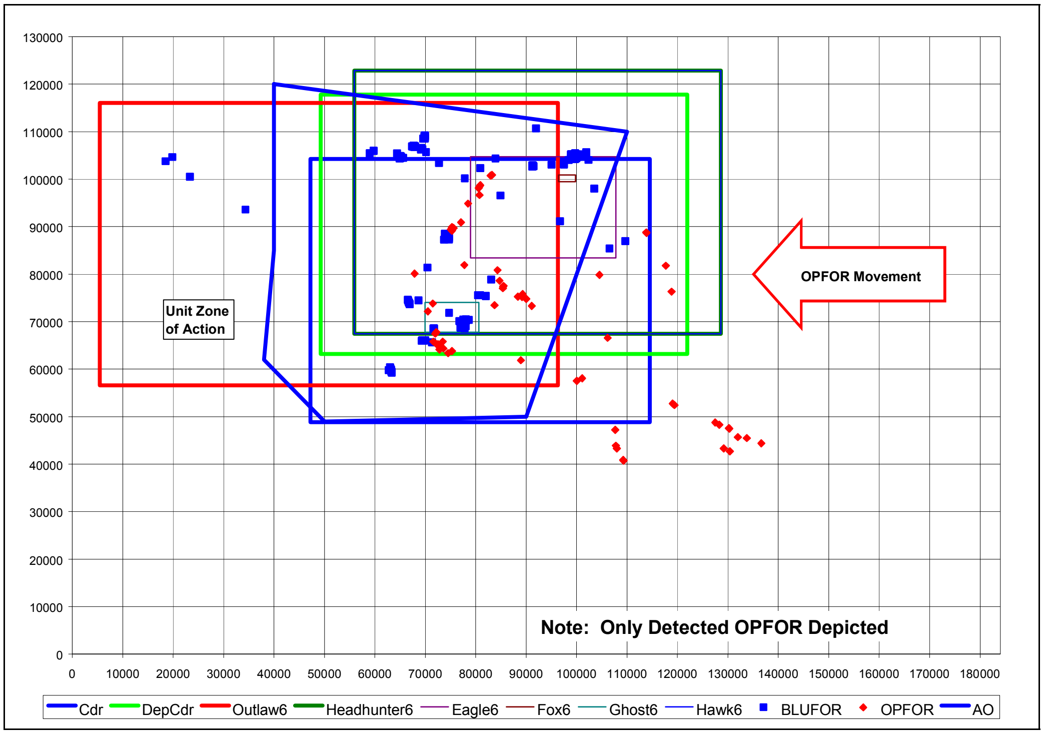
Map Area

Figure 27 displays the average area of terrain that was visible on the electronic map displays of commanders and staff officers over a designated time interval of 5 minutes. The Project Team selected the unit commander, the deputy commander, and the two control node officers in charge (Outlaw6 and Headhunter6) as representative of the amount of the battlefield that the staff would be viewing at critical points during the mission. The Project Team also decided to depict the battlefield area that the four maneuver team commanders displayed during the same interval as an indicator of where significant combat activity would be occurring. The size of the area being displayed has been averaged for the same 5-minute interval for each of the designated commanders and staff officers. This approach was necessitated because of the difficulty in synchronizing the displays to the same instant for the eight soldiers being tracked. For example, over the 7 1/2-hour duration of Trial 1, the experimental unit commander resized and/or changed the center point of his display 905 times. The deputy commander changed his display 1,363 times while one team commander changed his display 2,664 times. Other information being displayed includes the unit zone of action, the location of the unit's subordinate maneuver platoon leader vehicles, and the location of detected OPFOR systems. All data elements are based on 5-minute intervals, except for the location of the OPFOR which is available in 20-minute increments. An arrow indicating the general direction of movement for the OPFOR has also been added.

The rationale for this measure is to ascertain if the staff has a shared understanding of what is occurring at critical points during the mission. If the team commanders are focused on different portions of the battlefield than the staff or if the resolution of the staff's view is significantly different than that of the team commanders', then the amount of shared situational awareness among the unit comes into question.

The measure results depicted in Figure 27 indicate that at 0920 or about an hour into the mission, the unit commander and his staff had adjusted their displays to cover most of the unit zone of action and could also cover a significant portion of the battlefield in the area from which the OPFOR could be expected to appear. Only one staff officer (Outlaw6) was able to see back to areas where the unit still had forces. The team commanders (Eagle6, Fox6 Ghost6, and Hawk6) had zoomed their displays down into the immediate fight, focusing on their subordinates and the OPFOR.

Plotting the map area for the commander and three staff officers plus the four team commanders on the same picture creates a fairly complex presentation. While it is not possible to replicate it on paper, the electronic version of the output format can be modified to remove unwanted data, which can simplify the presentation. Additionally, each of the individual map areas can be also be highlighted if needed.



Note. AO = area of operations; BLUFOR = blue forces; Cdr = commander; DepCdr = deputy commander; OPFOR = opposing forces.

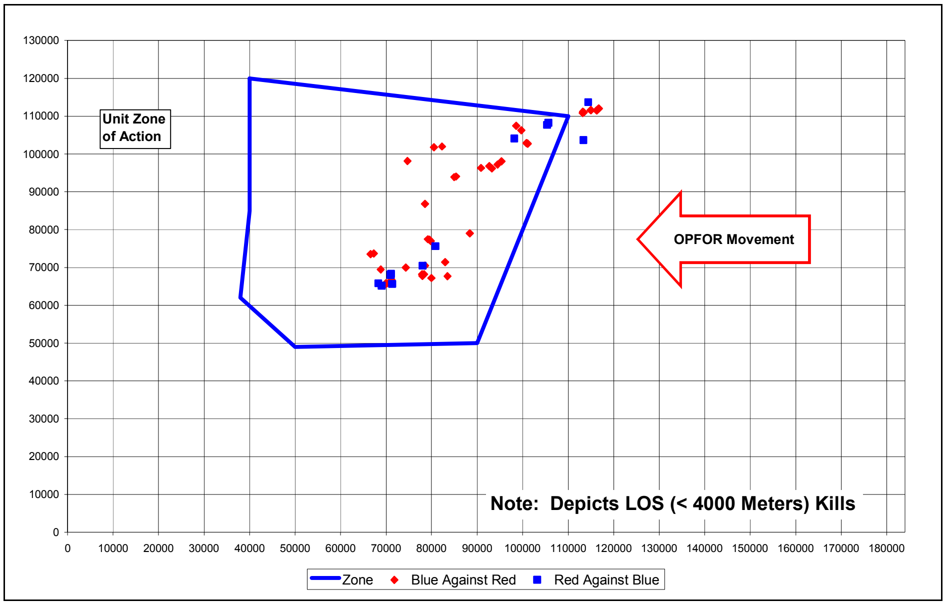
Figure 27. Map area at 0920.

Surprise Attack

There are two output formats associated with this measure – a picture and a pie chart. The Project Team used the range and the angle of attack based on the center line of individual combat systems to determine what constituted a surprise attack. If the engagement was less than 4,000 meters and the individual vehicle was attacked from the side or rear, then the attack was considered to be a flank engagement and thus a surprise attack. [Normally, if the targeted vehicle is aware of the location of its attacker, it orients its front, where its armor is thickest, to the threat. If it is attacked from the flank or rear, it is likely that the vehicle did not know that it was vulnerable to attack.] The picture (Figure 28) represents the locations where BLUFOR and OPFOR targeted vehicles were attacked from the flank or rear. The two graphs (Figures 29 and 30) depict the relationship of flank engagements to non-flank engagements for both sides. The solid pattern indicates the non-flank engagements; the diamond pattern indicates the flank pattern. Notes have been added by the authors.

The rationale for this measure was that if the staff was aware of the location of the OPFOR, it would ensure that everyone in the unit was aware of the situation and direct the unit's maneuver to either meet the threat head on or to a position where the OPFOR could be attacked from the flank or rear, increasing the probability of destroying the OPFOR while reducing the risk to the unit.

The results may indicate that, even with the inherent capabilities of the SC^4 system to provide a visual display of all friendly and detected OPFOR weapon systems locations that is being constantly updated, the closer the forces move toward each other, the less valuable that information is in protecting the force. For each side, the losses are surrounded by losses from the other side. A trained observer may conclude that the two forces had intermingled and/or bypassed each other which created or increased the vulnerability to flank or rear engagements.



Note. LOS = line of sight; OPFOR = opposing forces.

Figure 28. Surprise attack.

Figure 29 graphs the flank or rear engagements as a percentage of the total engagements against the BLUFOR experimental unit. Twelve percent of the engagements against the unit were from the flank or rear. Additional analysis of these engagements during an AAR by the unit participants may provide the reason for these losses. Figure 30 provides the same information about engagements against the OPFOR. While the total number losses for the OPFOR was greater than the unit's losses, the percentage difference is not nearly as great. Again, additional analysis is required to explain why the unit was not more effective in maneuvering forces or fires once the OPFOR had closed to within 4,000 meters of their locations.

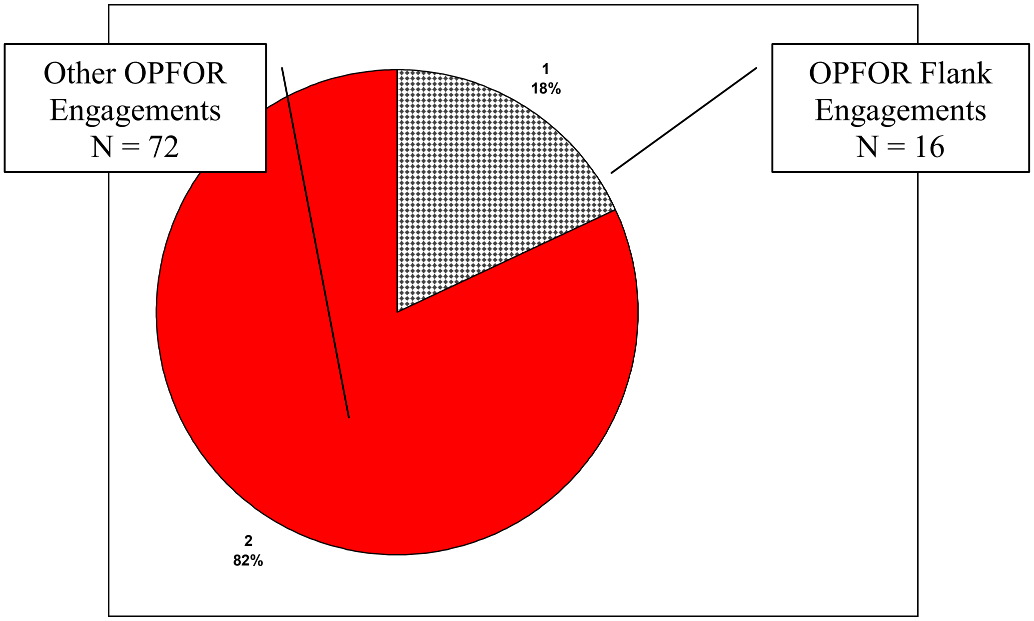


Figure 29. Opposing force (OPFOR) flank engagements against blue forces.

While the picture format provides a good representation of where the surprise attacks took place, information about the location of the shooter and whether it had been detected or not (thereby having its location displayed on the SC^4 system PVD) might be useful in determining if the unit was reacting quickly enough to an imminent threat to prevent losses. Including the total number of engagements on the graphs would make them more meaningful. Additionally, they should be combined to allow side by side comparisons.

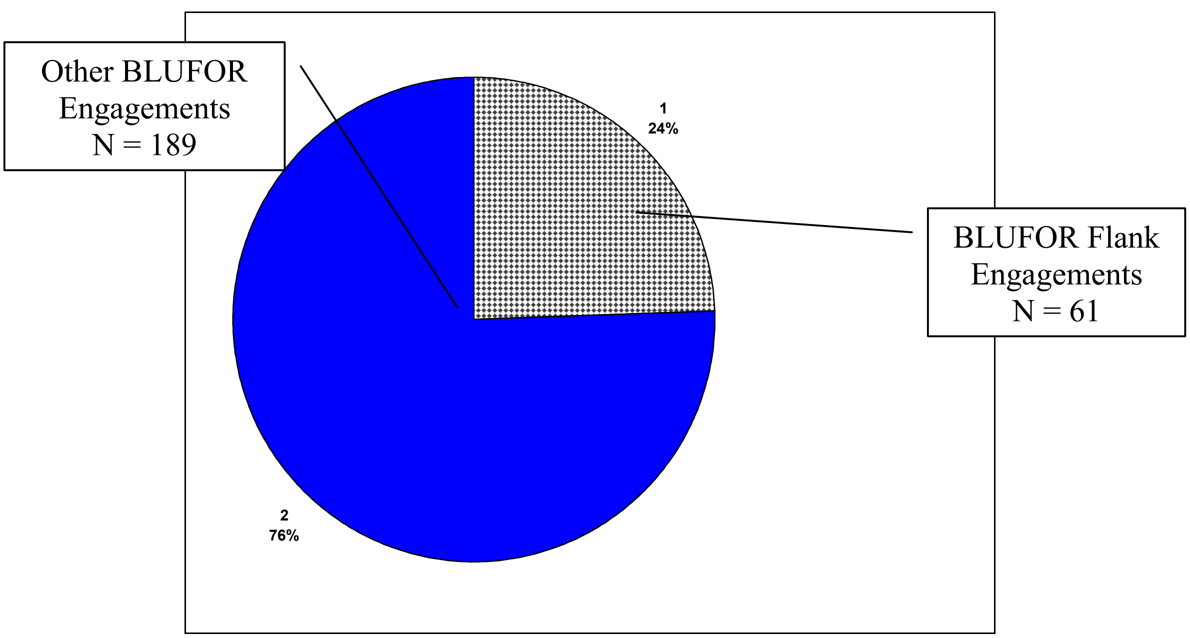
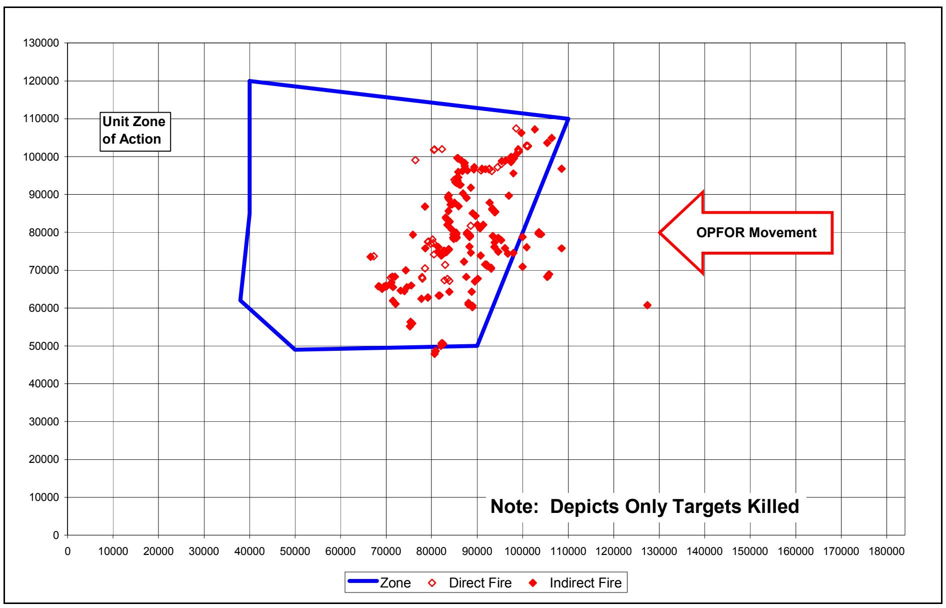


Figure 30. Blue forces (BLUFOR) flank engagements against opposing forces.

Fire Support Coordination

The Project Team developed two output formats for this measure: a picture and a bar graph. The picture (Figure 31) depicts the location where each individual OPFOR weapon system was killed by the experimental unit during Trial 1. The outlined diamond symbol represents the location where vehicles were destroyed by direct fire weapons. The solid diamond symbol represents the location where OPFOR were killed by indirect fire weapons. The unit zone of action has been plotted based on a table created by an observer and an arrow indicating the general direction of movement for the OPFOR has been added. The bar graph (Figure 32 relates the number of direct fire kills to the number of indirect fire kills.

The rationale for this measure is that if the staff has sufficient situational awareness as well as the ability to synchronize the fire support assets under its control, then the unit could inflict significant damage to the OPFOR before the enemy can close to within direct fire range. The farther away from the unit the OPFOR can be destroyed, the less risk there would be to the experimental unit.



Note. OPFOR = opposing forces.

Figure 31. Fire support coordination.

As can be seen in Figure 31, a majority of the OPFOR were killed with indirect fire weapon systems, with most of these occurring with the zone of action. There were some kills outside of the zone of action which means that the unit was able to interdict the movement of the OPFOR. Figure 32 relates the number of BLUFOR direct fire kills to the number of indirect fire kills. The data indicate that there were approximately three indirect fire kills for every one direct fire kill, which may indicate that the experimental unit was able to inflict significant damage to the OPFOR while minimizing its losses.

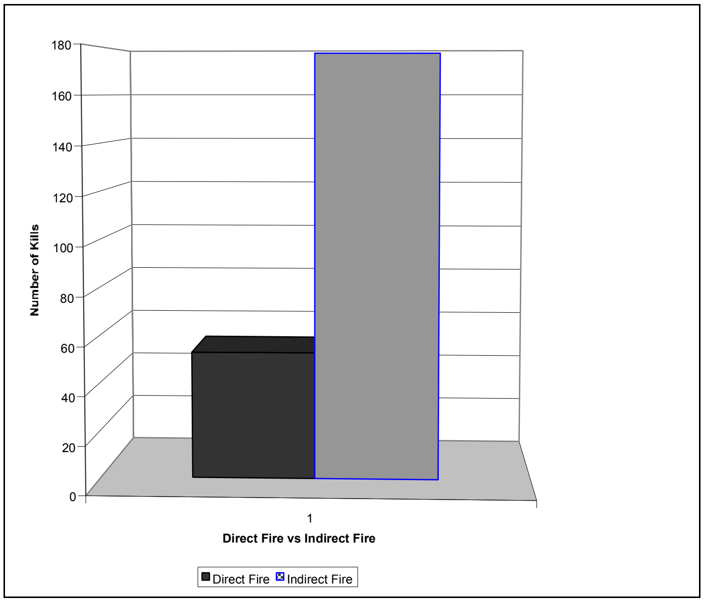


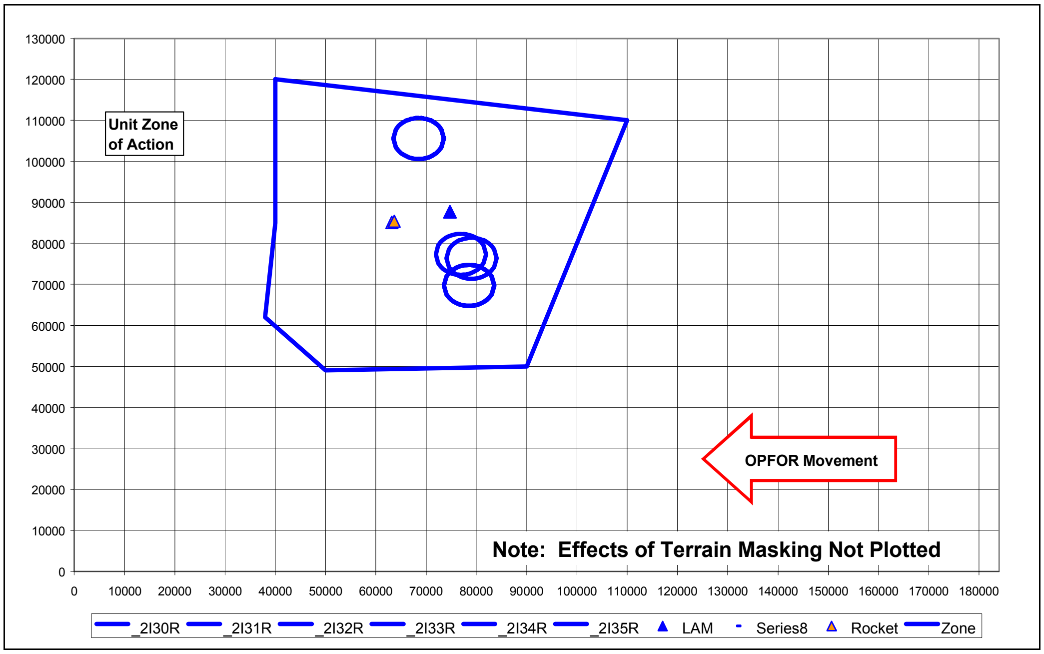
Figure 32. Blue forces fire support coordination graph.

Differentiating among the types of fires may improve the picture format for this measure. For example, each kill for a specific type of weapon might be given a different color or pattern. Another potential improvement might be to incorporate the bar graph into the picture to provide a quick visual ratio of direct fire to indirect fire kills without having to display the two formats simultaneously.

Air Defense Coverage

Prior to the start of FCC^2, the Project Team surmised the 12 indirect weapon systems (Long-range Attack Missile [LAM], Rocket, and 155mm Howitzer) controlled by the staff would be the critical assets most vulnerable to air attack. In Figure 33, these systems are represented by the triangular symbols. To establish if the unit's air defense systems could protect these critical assets, the locations of the six individual air defense weapon systems were entered into a worksheet which automatically calculated the range template for each weapon system. The range templates were then plotted. Since geographical information, such as mountains, was not being factored into the display, a note was added to remind the viewer that the masking effect of terrain was not being considered. This meant that the actual range template could in fact be more limited than shown. The direction from which potential air attacks could come was indicated by an arrow representing the general direction of OPFOR movement. The vehicle location data used to create the picture is available in 5-minute intervals.

During FCC^2, the unit's air defense systems came under the direct control of the staff. The Project Team projected that the location of the air defense systems in relation to critical assets may be an indicator of the staff's ability to monitor the location of those assets and to direct changes in locations based on the commander's priorities. With the relatively short range (5,000 meters), the air defense systems would need to be positioned very closely to the assets and to be mutually supporting if they were to provide a defense in depth against air attack.



Note. OPFOR = opposing forces.

Figure 33. Air defense coverage at 0900.

Fratricide/Collateral Damage

This measure looks at the instances where the unit attacked and destroyed either friendly combat forces (fratricides) or caused unintended damage to neutrals, non-combatants, and civilians (collateral damage). In addition to noting the time, the unit involved in the incident, a description of the target, and its location, the weapon system and ammunition employed along with the range are also tracked.

If the staff is keeping the rest of the unit apprised of non-combatant locations and other friendly forces locations and activities, there should be no instances of fratricide and very few instances of collateral damage caused by units equipped with advanced C^4I systems like the SC^4 that provide users with updated situational information every 60 seconds or less. Fratricide and/or collateral damage may indicate problems with situational awareness within a unit. The type of ammunition employed and the range may indicate if the unit used area-type or "dumb" ammunition against targets that should have been engaged with point-type or "smart" ammunition. Table 7 lists the fratricides and collateral damage that occurred during Trial 1.

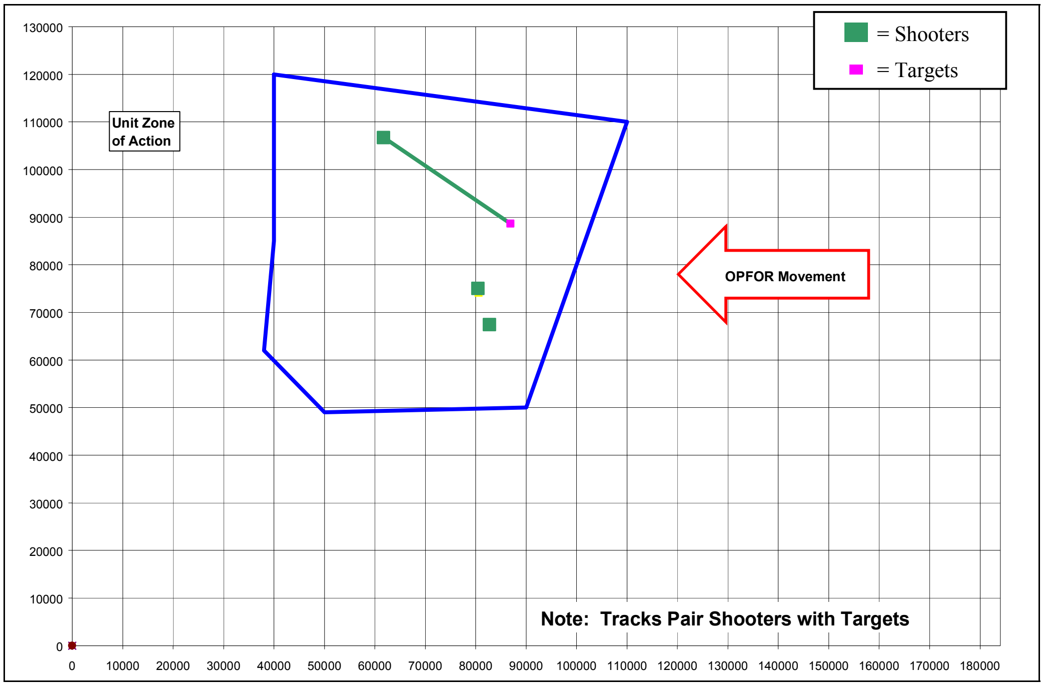
Table 7

Fratricides and Collateral Damage

Time	Unit	System	Ammo	Range	Target
9:53	_2E48R	VEH_ROB_PAM	PAM	2988	FRANC_VEH_LT_TRK
10:41	_2G110P	VEH_ROB_PAM	PAM	30994	CIV_DI_QUAD_E
11:31	_2G20	VEH_MAND_TRP_TRANS_CMD	German_35AP	880	CIV_DI_DUO_A
13:27	_2G20	VEH_MAND_TRP_TRANS_CMD	M792	112	CIV_DI_COL20_C

The collateral damage reported requires further analysis. As an artifact of the virtual simulation used to support experimentation during FCC^2, certain OPFOR units were disguised as civilians or non-combatants. This labeling allowed those units to approach elements of the experimental unit without drawing undue attention to themselves. On command, they would then attack the experimental unit without warning. Further analysis may determine if this was the case during this trial.

Figure 34 shows the location of the collateral damage incidents and the locations of the shooters who initiated the attacks during Trial 1. The large rectangles are the shooters. The smaller rectangles are the targets. Lines are used to pair shooters with targets. In two instances, the shooter and target were so close together that the line between them was merged into the location symbols. The legend was eliminated from this picture. The software code that generates this picture was sized to accommodate 50 potential collateral damage incidents. Every potential incident is automatically assigned a "Series" label which is displayed in the legend along with a label for an actual incident. The Project Team determined that this information would create confusion about the number of incidents being displayed.

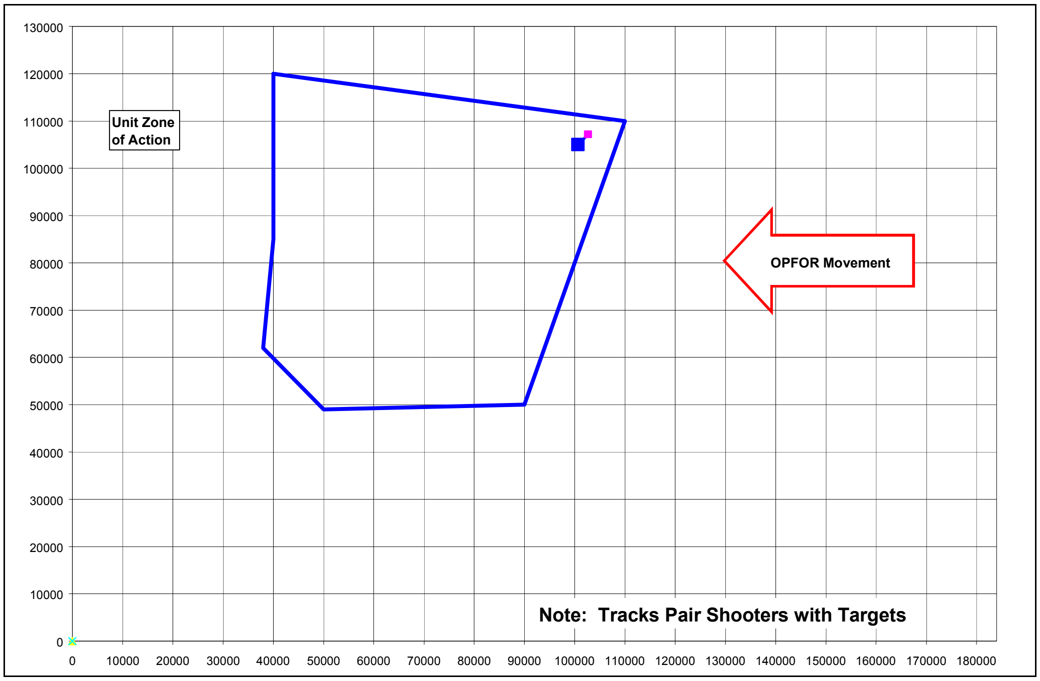


Note. OPFOR = opposing forces.

Figure 34. Collateral damage.

Figure 35 provides the same data for fratricides during Trial 1. Again the legend was eliminated. There was only one instance of fratricide: a friendly nation's light truck was destroyed by a PAM. Again the location of the shooter is indicated by the larger of the rectangles; the target location is the smaller rectangle. The line that connects the pair has merged into the symbols. Without other data to explain what precipitated the attack, this incident would be analyzed during the unit's AAR to see if tactics or procedures needed to be modified to prevent a recurrence.

Initially, the Project Team sought to combine the fratricides and collateral damage incidents into one picture. This combination was not technically feasible during this effort. The specific problem was linking two different sets of shooter-target combinations, yet differentiating between the two. Additional programming should be able to overcome this challenge. Additionally, adding the data table information into the picture would also be useful. To gain a full understanding of the measure's results as it is currently formatted, both the picture and the table need to be displayed simultaneously.



Note. OPFOR = opposing forces.

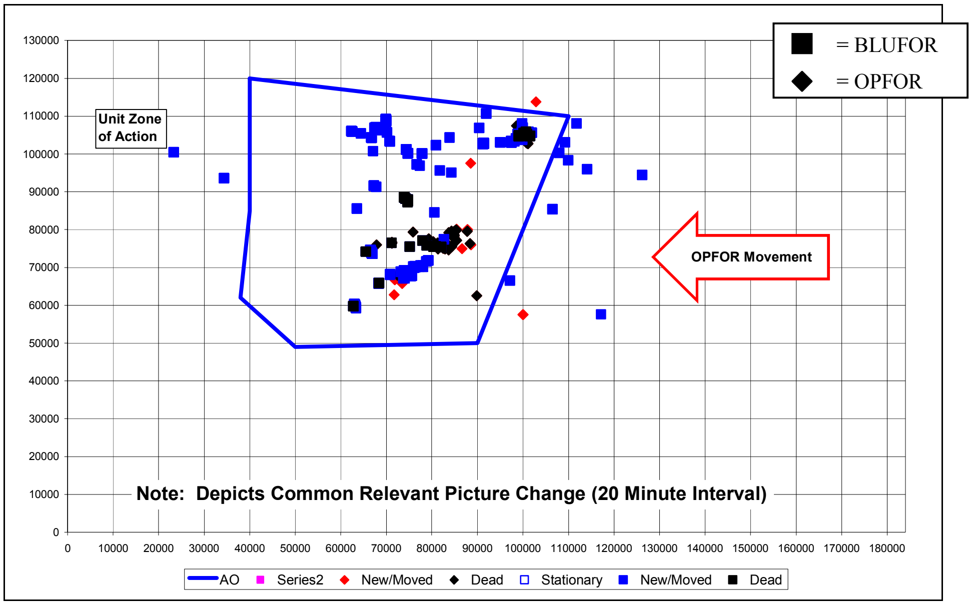
Figure 35. Fratricides.

Common Picture

To develop this measure (see Figure 36), the Project Team first obtained the location of every vehicle in the unit. This location is plotted using a red or blue outlined diamond or square. The vehicle was assigned the "Stationary" label. If there were not stationary vehicles, such as the case for the OPFOR, then Excel assigned the "Series" label. The location of the same vehicle 20 minutes later was then plotted. The 20-minute interval was used for two reasons: first, the Project Team thought that vehicle movements of less than 20 minutes in duration would not be visually detectable at the scale of terrain data being presented; and second, OPFOR information was only available in 20-minute intervals. This location was plotted in a solid red or blue diamond or square, and labeled as "New/Moved." This was the same category used to account for vehicles that may have been added to either the OPFOR or the unit since vehicle positions had been last recorded. If a vehicle was being reported as destroyed, it was plotted in a black diamond or square, and labeled "Dead."

An indicator of how much information the staff and others in the unit are sharing among themselves would be an analysis of the changes over time in the information that is being displayed on an individual soldier's PVD. This information would be a common starting point for most staff actions such as providing estimates, making recommendations, alerting the commander to changes in the situation, or developing courses of action. To start that analysis, the first step was to determine what information changes. The Project Team focused on the locations and status of detected OPFOR and unit vehicles since changes in locations and status would be readily discernible on a PVD.

The results obtained by this measure, at the scale being represented, required careful examination to detect significant changes, even at the 20-minute interval used to plot vehicle locations. Any movement, however insignificant, caused the vehicle to be plotted as “New/Moved.” Vehicles that were “Dead” continued to be plotted as each picture was being updated, so that the vehicles that had been killed during the current 20-minute interval could not be discerned from those killed in the preceding 20-minute interval or even earlier.



Note. OPFOR = opposing forces.

Figure 36. Common picture at 0920.

To fully realize the intent of this measure, additional information is required about the electronic PVD filters each FCC[2] unit participant had set on his system at the point in time that the picture was created. For example, a participant may have set the PVD to display aggregated unit symbols such as platoons or companies rather than individual vehicles. Rather than having hundreds of vehicle symbols, his display may have had only 10 or 15 unit symbols. He could have adjusted the display so that dead or killed vehicle symbols would not be displayed. He could have adjusted the display to remove or to leave OPFOR vehicle symbols that were not currently being observed by some sensor. The Project Team was not able, within the time available to the project, to integrate individual participant filter settings into the picture. Additionally, the amount of vehicle movement that would be considered significant needs to be defined, so that only those significant movement changes would be plotted. Also, newly killed vehicles need to be distinguished from previously killed vehicles.

Conclusions

During FCC^2, the Project Team implemented 20 measures, 19 of which were automated in that, once an initial set of criteria had been determined (such as the critical weapon systems to track, the number of unit and OPFOR weapons participating in the exercise, and unit zones of action), the output formats could be generated from trial data without further observer intervention. The orders distribution measure requires additional development to automate it. Further refinement is required to improve the utility of some of the measures as discussed under the particular measures.

Lessons Learned: Improve

This project built on the lessons learned from the previous projects and more fully realized the development of fully automated measures of command and staff performance. The implementation of the automated measures during FCC^2 provided an opportunity to test generating automated measures output formats in training conditions similar to those that are envisioned for future brigade-level and below battle staffs equipped with advanced digital C^2 systems. However, there are still issues that need to be addressed before these automated measures can become a meaningful part of training feedback in an AAR-type environment.

Observer Input

A key role for an observer in any training event is determine before hand what information will be needed to provide meaningful performance feedback. Even training feedback systems that rely heavily on automated measures need someone to determine which measures from the available library will apply to the specific event and to review the outputs to determine if the results should be incorporated into an AAR. Observations from trained observers are also required to put many of the measure outputs into context. All of the conditions involved with staff performance during a training event cannot be automatically derived. For example, while the amount of map area that is being displayed on a staff member's PVD can be determined, the data cannot reveal whether the staff member was actually looking at the display or attending to other duties, which may have caused him to ignore the information being displayed. A staff member simply could have left the display on and exited his vehicle. Also, some measures, such as fratricide and collateral damage, invariably will require a detailed examination of all the circumstances involved with those incidents. The measure output alerts the training participants that a problem exists, but does not get to the root cause. Without objective command and staff performance standards, all automated measures will need to be interpreted by SMEs who can provide standards based on their knowledge and experience.

Data File Size

After researching the capabilities in Microsoft® Excel, the Project Team realized that the quantity of records that would be produced during an FCC^2 trial could not be manipulated in Excel as planned. Recording 1,000 vehicle positions every five minutes for an eight hour trial produced 96,000 records which exceeded Excel's data handling capabilities. This caused the Project Team to go from Excel to Microsoft® Access. Adding an extra software package into the equation led to some minor difficulties in the design of the observer workstation. Instead of pushing a single button in order to develop a measure as planned, the user has to push a button in each software package. This leads to redundancy for the user as well as longer measure output development time. Additionally, more data tables were required than were planned. For example, the largest MMBL ASCII data file was eventually split into three different files so the information needed to build measures could be accessed more easily. Additionally, the sheer size of the files associated with FCC^2, Access databases in excess of 51 Megabytes and some Excel output files exceeding three Megabytes, created problems in transferring, copying, and printing operations. All of these challenges in handling data are essentially technology driven and can be overcome with more capable computer and communications hardware and software.

Missing Data

Working with the initial set of FCC^2 data, the Project Team discovered that there were numerous queries that were producing files with no data. This condition was not expected since it had not occurred during pre-implementation testing. As a result of having blank query files, the Microsoft® Excel macros would generate run-time errors which terminated further data processing necessary to create the output formats. To overcome these errors, the Project Team encoded the Excel macros to ignore empty data files. The Project Team also compared the raw ASCII data files with the FCC^2 Experiment naming convention for identifying unit, vehicles, and weapon systems. Several discrepancies were found which resulted in the Project Team changing queries to reflect actual conditions. Finally, the Project Team, based on input from MMBL personnel, determined that the output formats were not reflecting all activity that was occurring during the trials. An examination of the MMBL ASCII data files revealed that the file that matched vehicle locations with engagements was not catching every engagement. This file was then split by MMBL programmers into two data files which corrected the problem. This, in turn, led the Project Team to revise all queries requiring engagement data. With these changes, problems with empty data files were eliminated.

Data Manipulation

The goal for this project was to have the outputs from the automated measures to be available for use during the FCC^2 AARs which would be held each day. Based on previous experience, the Project Team had projected that it would take about two hours to produce the complete set of output formats. This would allow them to be used during FCC^2 AARs, which generally took place about two hours after the last significant combat action during a trial. Unfortunately, the amount of time to create the output formats greatly exceeded that estimate. It took an average of two hours of processing time for the software used by the MMBL to consolidate the data and produce the initial data tables for each trial; it took another 15-30 minutes to convert these data files to ASCII and post them to an MMBL intranet web page where the Project Team could access them; it took another 30-45 minutes to import the ASCII files into Microsoft® Access; and finally, it took an additional 45-60 minutes to build the measures, add titles, and save the output formats. The total amount of processing time from start to finish exceeded four hours. As a result, the results where not available for use during the FCC^2 AARs.

Lessons Learned: Sustain

Based on the experience of the Project Team during the FCC^2 implementation, as well as the discussion for improving each of the measures provided earlier in this report, several lessons were learned which may serve to sustain current efforts in implementing automated measures of command and staff performance and to act as a catalyst to initiated future research. These may be applicable to developers concerned with embedding training and, by extension, performance assessment methodology and tools into future digital C^4I systems at the brigade level and below. These lessons are provided as issues to be addressed in future research.

Data Visualization

Continued efforts are needed to optimize the presentation of automated measure results, especially for graphical and pictorial formats, to soldiers. The goal should continue to be to provide information that soldiers can readily understand without facilitator or trainer intervention. Formats should be able to relate command and staff performance to battlefield conditions. Users should be able to track or "drill down" from MOEs (outcomes) to MOPs (processes). Finally, through the use of interactive media, soldiers should be able to control the type and amount of automatic performance feedback information that they are receiving as well as the format in which it is being displayed not only in AARs but also from their operational C^4I systems.

Commercial Business Software

Using a widely available commercial off-the-shelf business software package such as Microsoft® Office provides inexpensive development tools to create prototype automated measures. All of the components that would be required to provide measures of command and staff performance to an automated AAR process are available: data storage and retrieval (Access), charting and graphing tools (Excel), and tools to present the results to the training participants (PowerPoint®). Applying this same type of software to operational automated measures of command and staff performance would benefit users of such systems. Most experienced business software users would need little or no additional training to operate the software and to work with the results from the measures. Finally, as these commercial business software programs incorporate additional functionality, which may make them even easier to integrate into C^4I systems, upgrades should incur little or no additional training costs.

User Tools Development

Today's measures, such as the prototype automated measures designed and developed during this effort may not apply to future training conditions. There is a need for future staff trainers to be able to design their own measures without requiring an extensive background in programming. An automated measures development package that gives users the option of using existing measures or modifying them, or creating entirely new measures is needed. If the tools used to work on measures development or modification are not already integrated into operational C^4I systems used by the training participants, they should be based on whatever commercial business software that is being widely used throughout the Army.

Future Staff Performance Standards

Further development efforts on automated performance measures requires research to develop objective performance standards for future C^2 organizations. The research should include intrinsic measures where the organization is provided on-going indicators of its performance, such as Orders Distribution, where they could determine by the systems and resources immediately available to them if everyone is using the same operations overlay, and extrinsic measures, such as Kill Distance, where additional post-training processing would be required to establish the organization's overall performance. Team behaviors and processes, soldier-machine interface, and soldier-machine task allocation issues should be included in the research to ensure both group dynamics and individual contributions can be isolated and analyzed for their impact to the overall performance of the organization.

Pre-Planned Measures Implementation

Automated performance measurement capabilities need to be fully integrated into the design of advanced digital C^4I systems. If data are not being recorded and stored, it is not available for other purposes such as training feedback. Data storage may be an encumbrance/obstacle with operational C^4I systems that dump data when they are powered down. In such instances, alternative, dedicated data storage systems may have to be specifically developed for recording performance data for later analysis. The feasibility of including this capability may increase and the costs associated with it may decrease as large capacity data storage devices become more compact, tolerant of unstable operating conditions, and power efficient. As described earlier, handling large amounts of data associated with automated performance measures can overwhelm operational C^2 systems. Research efforts are needed to optimize collecting, processing, assembling, and distributing data for AARs.

Summary

Digital C^4I systems provide unlimited potential to assess individual soldier, small group, and collective performance data. They have organic capabilities that need to be exploited to automatically collect, analyze, and portray data. Such data collection, accompanied by capabilities for analyzing and displaying the results in terms of processes and outcomes, can support both intrinsic and extrinsic feedback. By "intrinsic feedback," we mean the information that immediately informs the user that something is not right, or that more information is available, or that some critical information need is being answered. This information, provided by means of on-board systems and remote sensors, can be provided as an operational capability as well as during training. "Extrinsic feedback" allows the user to look back on an operation or training exercise and identify ways to sustain or improve performance through optimal use of information systems.

Accessing the collected performance data and making it intelligible to observers or to the unit in training has to become a common and routine feature of all training and operational systems. The particular data elements that are related to performance, the analytic tools that fuse data to provide useful feedback, and the format for feedback reports need to be optimized from a human factors point of view to allow for clear and immediate impact. Continued research and development of automated measures of performance that provide intrinsic and extrinsic feedback is an imperative for training the Army's future brigade-level and below forces equipped with advanced digital C^4I systems.

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Appendix A

List of Acronyms

AAR	after action review
ADA	air defense artillery
AO	area of operations
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ARPA	Advance Research Projects Agency
ARSI	ARPA Reconfigurable Simulator Initiative
ASCII	American Standard Code for Information Interchange
BCR	Battle Command Reengineering
BCV	battle command vehicle
BLEFR	Battle Lab Experiment Final Report
BLEP	Battle Lab Experiment Plan
BLUFOR	blue forces
BOS	battlefield operating system
C^2	command and control
C^2V	command and control vehicle
C^4I	command, control, communications, computers, and intelligence
CCIR	commander's critical information requirements
Cdr	commander
COTS	commercial off the shelf
CSS	combat service support
DA	Department of the Army
DC^4I	Prototype Methods for the Design and Evaluation of Training and Assessment of Digital Staffs and Crewmen
DC^4I-2	Refinement of Methods for the Training and Assessment of Digital Staffs
DC^4I-3	Performance Evaluation, Training, and Future Requirements for Digital Skills
DCA	Data Collection and Analysis System
DepCdr	Deputy Commander
DIS	distributed interactive simulation
FCC^2	Future Combat Command and Control
FLOT	forward line of own troops
FOV	field of view
FV	fighting vehicle
GUI	graphical user interface
HPT	high payoff target
HVT	high value target

IDF	indirect fire
IFV_APC	infantry fighting vehicle/armored personnel carrier
LAM	long-range attack missile
LOS	line of sight
MCOO	modified combined obstacle overlay
MMBL	Mounted Maneuver Battlespace Lab
ModSAF	Modular Semi-Automated Forces
MOE	measures of effectiveness
MOP	measures of performance
MTR	mortar
NCO	noncommissioned officer
OPFOR	opposing forces
OPORD	operations order
OWS	Observer Work Station
PAM	precision attack missile
PDU	protocol data unit
PLT LDR	platoon leader
PPT	Microsoft® PowerPoint®
PVD	plan view display
SAG	SME Advisory Group
SC^4	Surrogate Command, Control, Communications, and Computers
SITREP	situation report
SME	Subject Matter Expert
SOP	standing operating procedure
SOV	staff operations vehicle
SPOTREP	spot report
STAARS	Standard Army After Action Review System
TRADOC	U.S. Army Training and Doctrine Command
UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle
VEH_ROB_MTR	vehicle robot mortar
VTC	video teleconference

Appendix B

Future Combat Command and Control Experiment Setting

The implementation of the automated measures developed was dependent upon the Future Combat Command and Control (FCC^2) environment. Therefore, descriptions of the participants, the equipment used by the participants, and equipment used to collect data in the FCC^2 experiment follow.

Participants

The unit participating in the experiment was an active Army cavalry squadron staff with its subordinate company commanders participating. One company brought drivers and gunners to man several future combat vehicle simulators. As shown in Figure B-1, the squadron staff, which operated in a virtual simulation, included the commander and 13 staff officers and non-commissioned officers (NCOs). The commander and staff were reconfigured into two battle command vehicles (BCVs) and two staff operations vehicles (SOVs), or nodes. The battle command reengineering aspect of the FCC^2 experiment was focused on this group of 14 soldiers. The node functions and job responsibilities for each staff member were left to the discretion of the squadron commander, who was allowed to reorganize the staff as he gained experience in operating the Surrogate Command, Control, Communications, and Computers (SC^4) system.

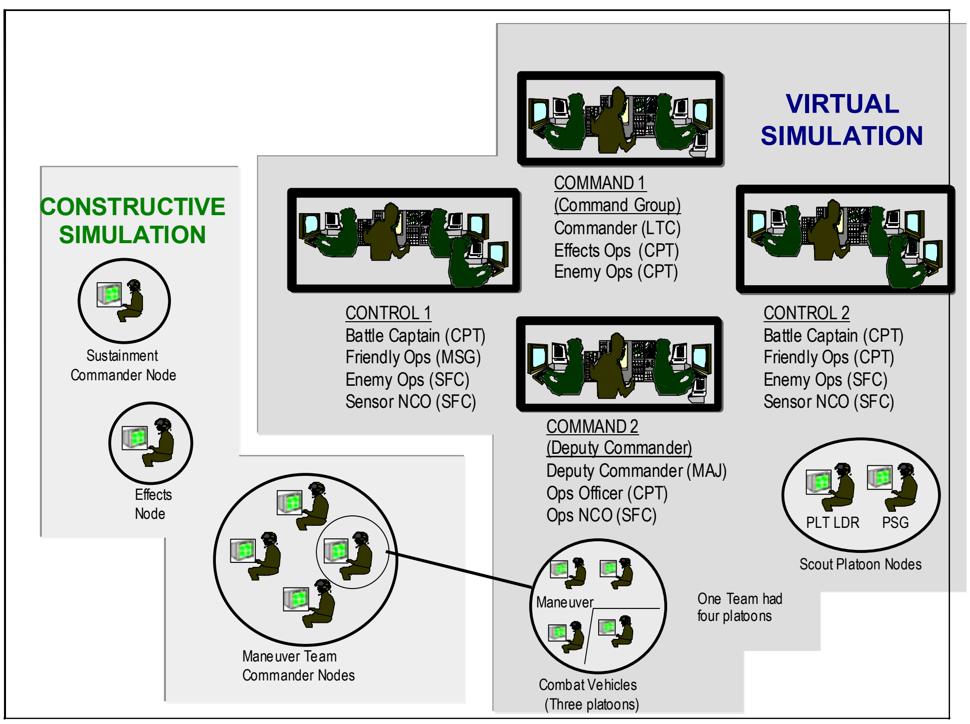


Figure B-1. Battle Command Reengineering IV staff structure.

Table B-1 shows the call signs and associated node positions for the commander and 13 primary staff members. In this report, these participants will often be identified by their call signs, especially in tables that appear in the Results section.

Table B-1

Staff Member Call Signs and Titles

Call Sign	Title	Node
Cougar6	Squadron Commander	Command 1
Cougar62	Enemy Operations Officer	Command 1
Cougar69	Effects Officer	Command 1
Cougar3	Deputy Squadron Commander	Command 2
Cougar32	Operations NCO	Command 2
Cougar35	Operations Officer	Command 2
Outlaw6	Battle Captain	Control 1
Outlaw2	Enemy Operations NCO	Control 1
Outlaw3	Friendly Operations Officer	Control 1
Outlaw59	Sensor NCO	Control 1
Headhuner6	Battle Captain	Control 2
Headhunter2	Enemy Operations NCO	Control 2
Headhunter3	Friendly Operations Officer	Control 2
Headhunter59	Sensor NCO	Control 2
Eagle6	Company Commander	Constructive Simulation
Fox6	Company Commander	Constructive Simulation
Ghost6	Company Commander	Constructive Simulation
Hawk6	Company Commander	Constructive Simulation

Note. NCO = non-commissioned officer.

Other squadron personnel involved in the experiment included: six company commanders, six deputy company commanders, six maneuver platoon leaders, one scout platoon leader, one scout platoon sergeant, nine gunners, and 15 drivers.

Materials

The FCC^2 used emulation as well as constructive and virtual simulators. Figure B-2 shows the layout of the SC^4 system in the BCVs and SOVs. The SC^4 system included the following capabilities:

- Command and Control (C^2) Plan View Display (PVD), represented by the Modular Semi-Automated Forces (ModSAF) two-dimensional PVD. On the PVD, the commander and the staff are able to view movements of all of their own systems, as well as any opposing force (OPFOR) units detected by satellite or other sensors. Overlays can be drawn on the PVD, users can add labels or other notes, and there are tools that show past events and project future movements.

- Stealth display, providing a 3-dimensional representation of the battlefield with all of the systems that are visible on the PVD (i.e., friendly and detected OPFOR).

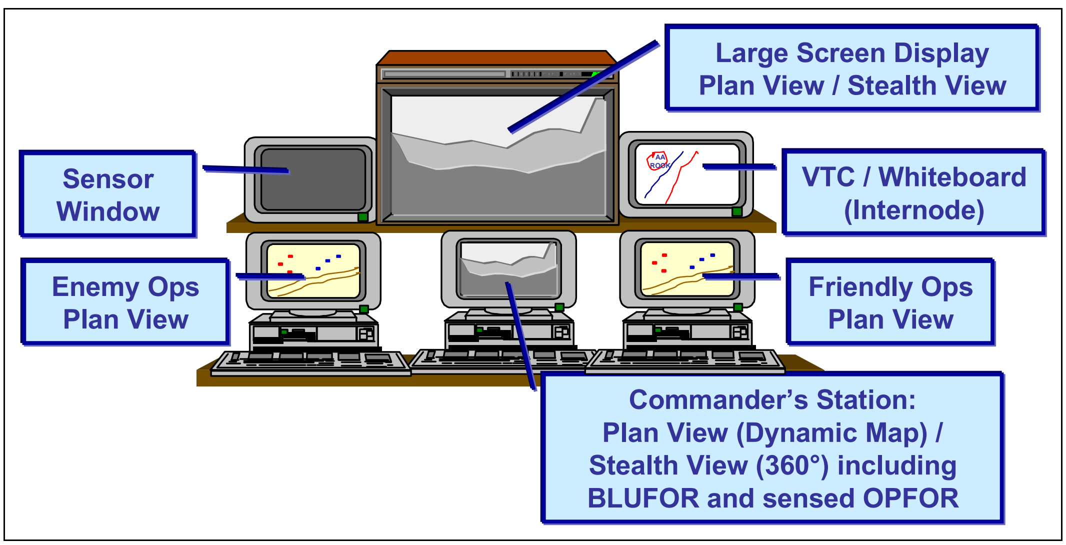
- Video teleconference (VTC) capability linking the commander and the staff.

- Collaborative whiteboard capability, to allow the commander to present his intent and guidance to the staff visually and quickly. Users who are part of the whiteboard session can show snapshots from their PVDs, draw in different colors on those images, add clipart-style labels and icons, and type words onto the whiteboard.

- Large screen display, providing a three-dimensional representation of the battlefield with all of the systems that are visible on the PVD, Stealth, whiteboard, or unmanned aerial vehicle (UAV) screens.

- Digitized modified combined obstacle overlay (MCOO), produced automatically for the large screen display, rather than as a manually produced intelligence overlay.

- Satellite imagery, acting as the electro-optic satellite sensor to deliver a direct downlink imagery feed.



Note. BLUFOR = blue forces; OPFOR = opposing forces; VTC = video teleconference.

Figure B-2. Surrogate command, control, communications, and computers system setup.

Vehicles and weapon systems were represented in either constructive or virtual simulation. Constructive simulation (ModSAF) was used to generate and control the OPFOR, friendly forces below the company level, and unmanned vehicles replicating both aerial and ground sensors (referred to as UAVs and UGVs, respectively). Constructive simulation workstations were used by the Sustainment Team Commander, the Effects Team Commander, and the four Maneuver Team Commanders. The remainder of the extended training audience was in virtual simulation.

In the virtual environment, simulators were used to represent several vehicles. These included the battalion commander and deputy commander vehicles which were represented by the Advanced Research Projects Agency (ARPA) Reconfigurable Simulator Initiative (ARSI) simulator and an ARSI mockup, respectively; and BCVs and SOVs which were represented by command and control vehicle (C^2V) mockups. Scout vehicles and the manned platoon vehicles of three maneuver teams were represented by Future Combat Vehicle mockups. The virtual and constructive environments were linked by means of distributed interactive simulation (DIS) to form the seamless battlefield environment for the participants.

The FCC^2 experiment trials were based on tactical operations that an Army battalion, equipped with an advanced digital command, control, communications, computers, and intelligence (C^4I) system, might be expected to conduct in the year 2010 and beyond. The virtual terrain chosen for the experiment was northeastern Bosnia-Herzegovina, centered on the city of Tuzla. This terrain is extremely mountainous with limited ground mobility corridors. Figure B-3 shows the experiment terrain map with a battalion area of operations superimposed.

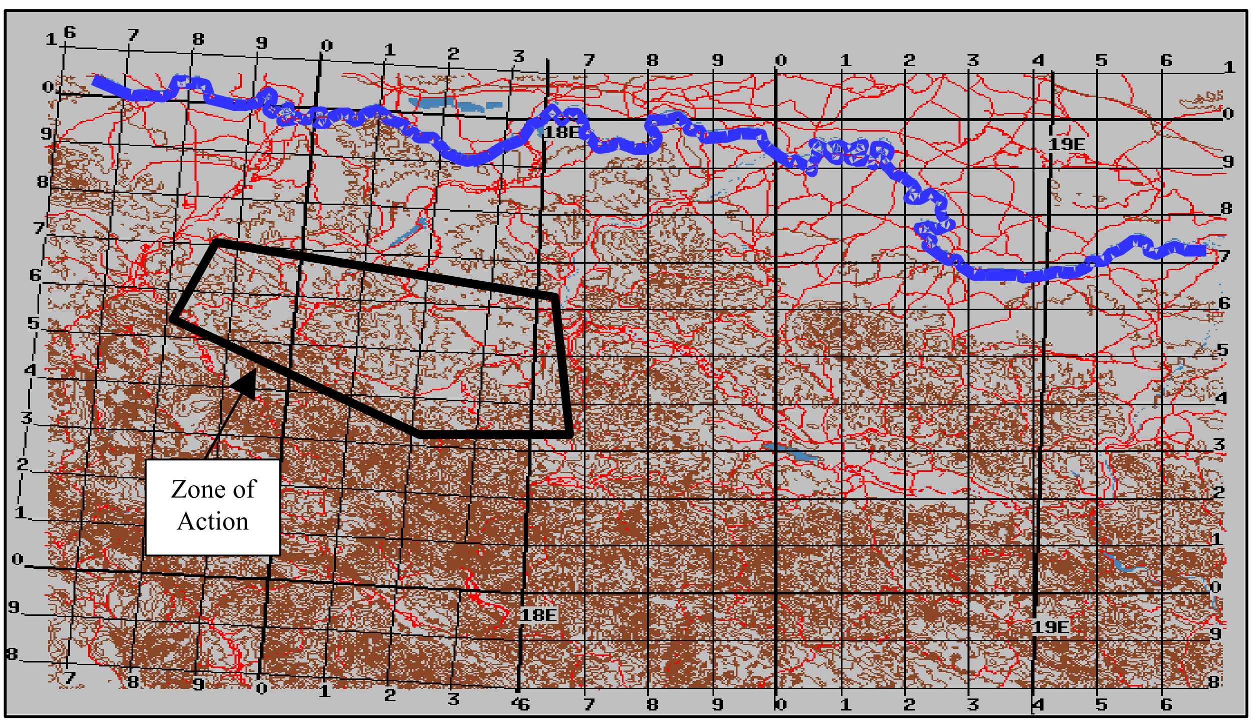
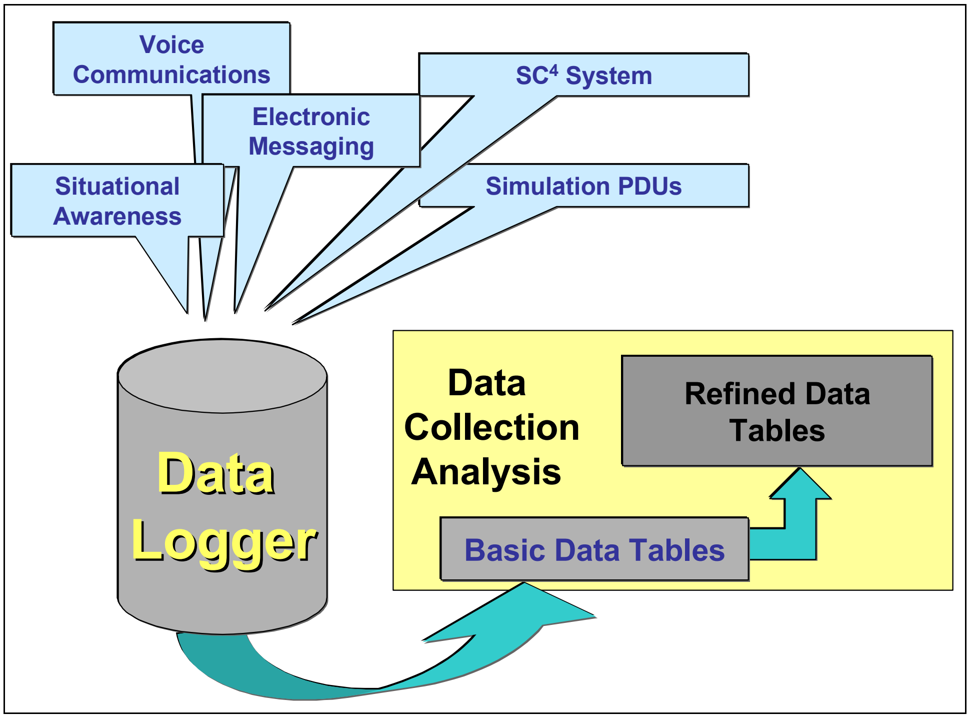


Figure B-3. Future Combat Command and Control terrain map.

The FCC^2 experiment data were collected and processed by the Data Collection and Analysis System (DCA). Figure B-4 illustrates key aspects and functions of the DCA. Information about SC^4 system usage, electronic messaging, voice communications (but not content), displayed situational awareness, and the status of major combat systems in the constructive simulation driving the experiment were recorded by three separate systems, collectively referred to as the data logger. Using database extraction tools, the DCA would initially create a series of basic data tables. These tables would be subsequently refined into more advanced tables which answered specific questions posed by various researchers. These refined tables were the starting point for output formats of the automated measures developed during this project.



Note. PDU = protocol data units; SC^4 = surrogate command, control, communications, and computers.

Figure B-4. Future Combat Command and Control data collection system.

Appendix C

Automated Measures of Command and Staff Performance
Categorized by Team Process Skill Dimensions

Adaptability

1. CSS Locations – Location of types of combat service support (CSS) assets at a specified time period.
   a. Operational definition: Location of CSS supply points and/or resupply vehicles (e.g., fuel, ammunition) in relation to unit locations on the terrain at critical points during the mission (start of exercise, first indirect fire engagement with opposing forces [OPFOR], first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission).
   b. Rationale: Identify if the staff's mission planning had incorporated sufficient flexibility to respond to unanticipated requirements, such as a platoon running out of fuel or ammunition during heavy combat or at a critical point in the mission. If the supply points or resupply vehicles were located where they were needed when they were needed, even from an unforeseen requirement, an inference could be made that the staff had adequately planned.
   c. Output: Picture

2. Node Locations – Location of each node in relation to major subordinate units at a specified time period.
   a. Operational definition: Location of each node on the terrain at critical points during the mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission).
   b. Rationale: Location of the unit's command and control (C^2) nodes may indicate the ability of the staff to handle different requirements simultaneously while keeping positioned to maintain communications with all subordinate elements, and maintaining operational and physical security.
   c. Output: Picture

Performance Monitoring and Feedback

1. Effects of Targeting – Depiction of high value targets (HVTs)/high payoff targets (HPTs) and the degree of attrition each suffered during a specified time period.
   a. Operational definition: For targets that the commander has designated as HVTs/HPTs (e.g., tanks, artillery, air defense systems, C2 nodes), calculate number of kills (catastrophic, firepower, mobility) over time and location and time of each target kill. Also calculate time first detected, time engaged, and time killed for each target. Identification of HVTs/HPTs will be provided prior to start of exercise.
   b. Rationale: Destruction of HVTs/HPTs by the weapon systems that are under the control of the unit's staff may be an indicator of the staff's ability to effectively monitor their

unit's performance against the desired result and to provide necessary feedback to the commander or guidance to subordinate units to get back on track.

c. Output: Picture, line graph, and/or table

Shared Situational Awareness

1. Map Area – Square kilometers of battlefield displayed for each staff member at a specified time period.
   a. Operational definition: Center points of each staff personnel's plan view display (PVD) screen displayed by grid coordinates at critical points during the mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission). The view size may be affected by the size of the open PVD/SC^4 [Surrogate Command, Control, Communications, and Computers] window, the scale of the map selected, and the use of SC^4 tools. Picture formats of this output should enable visual comparison of visible map relative to total map and relative to other users.
   b. Rationale: May indicate whether the staff has a shared understanding of what is occurring at critical points during the mission. If the team commanders are focused on different portions of the battlefield than the staff or if the resolution of the staff's view is significantly different than that of the team commanders', then the amount of shared situational awareness among the unit comes into question.
   c. Output: Picture

2. Surprise Attack – Depiction of blue forces (BLUFOR) in relation to OPFOR when BLUFOR were attacked for flank or rear engagements during each mission.
   a. Operational definition: Location on battlefield of flank or rear direct fire engagements on OPFOR and BLUFOR vehicles: attacks from a position that is greater than 45 degrees and less than 315 degrees of the hull orientation of the vehicle being attacked. The orientation of the vehicle is considered to be zero degrees for this calculation. Direct fire engagements are those that occur at ranges of 4,000 meters or less. Calculate the total number of engagements, the number of flank or rear engagements, and the number of non-flank or non-rear engagements. Data collection should start at first direct fire engagement with OPFOR.
   b. Rationale: If the staff was aware of the location of the OPFOR, it would ensure that everyone in the unit was aware of the situation and direct the unit's maneuver to either meet the threat head on or to a position where the OPFOR could be attacked from the flank or rear, increasing the probability of destroying the OPFOR while reducing the risk to the unit.
   c. Output: Picture and/or pie chart

3. Fire Support Coordination – Comparison of OPFOR kills due to direct fire and indirect fire during each mission.
   a. Operational definition: Location on the battlefield of each OPFOR kill due to indirect fire as well as each OPFOR kill due to direct fire from units controlled by the battalion staff. Additionally, number of OPFOR kills due to indirect fire from units controlled by

the battalion staff to OPFOR kills due to direct fire controlled by battalion subordinate units.

   b. Rationale: If the staff has sufficient situational awareness as well as the ability to synchronize the fire support assets under its control, then it could inflict significant damage to the OPFOR before the OPFOR can close to within direct fire range. The farther away from the unit the OPFOR can be destroyed, the less risk there would be to the experimental unit.
   c. Output: Picture and/or bar graph

4. Air Defense Coverage – Depiction of air defense system range templates overlayed on the location of the unit's critical assets taken at a specified time.
   a. Operational definition: Location of air defense systems on the battlefield, their range templates, and the critical assets they are covering at critical points during each mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty; friendly losses exceed 30%, and last engagement during mission).
   b. Rationale: Location of air defense systems in relation to critical assets may indicate if the staff is monitoring the location of subordinate units and directing changes in air defense coverage based on the commander's priorities.
   c. Output: Picture

5. Fratricide/Collateral Damage – Depiction of the location, unit(s) involved, and results of fratricide and collateral damage during each mission.
   a. Operational definition: Each instance of attack on BLUFOR vehicles and/or personnel by weapon systems under the unit’s control during a mission. Data should reflect firing unit ID, echelon of controlling headquarters, type of weapon, time of engagement, distance between the shooter and the victim, and damage to the targeted BLUFOR unit. In addition, report each instance of attack on non-combatant or civilian vehicles and/or personnel by weapon systems under the unit’s control during a mission. Data should reflect firing unit ID, echelon of controlling headquarters, type of weapon, time of engagement, and damage to the targeted non-combatant vehicle and/or personnel. When presented in picture format, the data should also depict trace lines between the shooter and victim.
   b. Rationale: If the staff is keeping the rest of the unit apprised of non-combatant locations and other friendly forces locations and activities, there should be no instances of fratricide and very few instances of collateral damage caused by units equipped with advanced C^2 systems like the SC^4 that provide users with updated situational information every 60 seconds or less. Fratricide and/or collateral damage may indicate problems with situational awareness within a unit. The type of ammunition employed and the range may indicate if the unit used area-type or “dumb” ammunition against targets that should have been engaged with point-type or “smart” ammunition.
   c. Output: Picture and/or table

6. Common Picture – Difference between electronic map displays at specified time periods.
   a. Operational definition: Comparison of the battlefield with BLUFOR and detected OPFOR at critical points during each mission (start of exercise, first indirect fire

engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission) and 30 minutes after each critical point. The pictures will indicate which previously detected OPFOR vehicles disappeared and which ones were newly detected between the two times. Comparisons will be made among various duty positions to determine the commonality of displays among the staff.

b. Rationale: Data will identify if the staff is sharing a common picture of the battlefield, which may be one indicator of shared situational awareness.

c. Output: Picture series

Communication

1. Overlay Use – Depiction of what graphics each command post had on its decision map at a specified time.
   a. Operational definition: Number of staff members that are showing, on their PVD, the same operations overlay file that the battalion commander is showing on his PVD at critical points during each mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission). These data should be reported as a percentage by dividing the number of staff members showing the same overlay file as the commander by the total number of staff members. If possible, report by duty position and operations overlay file name, those staff members who are not showing the same file as the commander at critical points in time.
   b. Rationale: The data may indicate whether the commander and his staff are using the same graphic control measures to monitor and control subordinate units. If they are not, then there is a significant potential for miscommunication and a breakdown of situational awareness within the unit. Measures the behaviors related to synchronizing actions, passing information in timely and efficient manner, and facilitating performance of other team members.
   c. Output: Table

Coordination

1. Damage to BLUFOR/OPFOR Systems – Number and type of BLUFOR/OPFOR systems out of action and what damaged or destroyed them during each mission.
   a. Operational definition: Number of BLUFOR/OPFOR tanks, artillery, and air defense system kills by various categories of weapons for each mission.
   b. Rationale: More indirect fire kills than direct fire kills may indicate that the staff has effectively coordinated fires. Also, the distribution of losses in the unit due to indirect fire and indirect fire from the OPFOR may indicate whether the staff was successful coordinating types of fire. Indirect weapon systems, due to their longer ranges, are habitually employed to attack the other side's indirect fire weapon systems.
   c. Output: Bar graph

2. <u>Degradation of Forces</u> – Depiction of the relative combat power of maneuver forces over time for both OPFOR and BLUFOR during each mission.
   a. <u>Operational definition</u>: Cumulative rate of OPFOR destruction in 20-minute intervals from the first engagement until the last OPFOR kill for each mission. In addition, cumulative rate of BLUFOR destruction in 20-minute intervals from the first engagement until the last BLUFOR kill for each mission.
   b. <u>Rationale</u>: Rapid destruction of the OPFOR reduces the risk of losses to the friendly unit. The rate of loss also may indicate battle tempo during the mission and whether the staff is coordinating the efforts of the unit to inflict the maximum number of losses in the shortest period of time.
   c. <u>Output</u>: Line graph

3. <u>Counterreconnaissance Effectiveness</u> – Effectiveness of the BLUFOR counterreconnaissance effort during each mission.
   a. <u>Operational definition</u>: Location where each OPFOR reconnaissance asset was detected and the location where each detected OPFOR reconnaissance asset was killed (catastrophic, firepower, or mobility).
   b. <u>Rationale</u>: May indicate if the staff was coordinating fires effectively to negate the OPFOR ground reconnaissance effort. If the OPFOR cannot detect the unit, the unit reduces its vulnerability. OPFOR ground reconnaissance vehicles are high priority, HPTs that, doctrinally, should be among the first targets attacked after they have been detected.
   c. <u>Output</u>: Picture

4. <u>Artillery and Counterfire Radar Coverage</u> – Depiction of BLUFOR artillery templates (by unit or type) overlaid on the location of the unit's subordinate elements at a specified time.
   a. <u>Operational definition</u>: Location of artillery systems on the battlefield and their range templates at critical points during each mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission).
   b. <u>Rationale</u>: May indicate whether the staff is effectively coordinating the indirect fire assets it directly controls to support both its subordinate units and the commander's intent and concept of the operation. Typically, indirect fire weapon systems, while geographically dispersed, are positioned where they can mass timely fires at decisive points in the operation and attack targets of opportunity while reducing their exposure to OPFOR counterartillery fires.
   c. <u>Output</u>: Picture

5. <u>Kill Distance</u> – Distance between shooter and target.
   a. <u>Operational definition</u>: Distance between OPFOR/BLUFOR weapon system killed and BLUFOR/OPFOR system that killed it. Categorize data by indirect weapon and direct fire systems separately. Scatterplot with a trend line will reveal how far the killed systems were from the system that killed them.
   b. <u>Rationale</u>: If the staff was effectively coordinating the fires of the weapons it directly controlled, then the majority of the kills they obtained should be nearer the maximum effective range of the weapon rather than the minimum effective range of the weapon.

c. Output: Line graph and/or table

6. Sensor - Shooter Time Lag – Time between first detection of OPFOR HVT/HPT by BLUFOR and when the OPFOR HVT/HPT was killed during each mission.
   a. Operational definition: Amount of time between first detection of an OPFOR HVT/HPT and when it was killed. Also, location where they were first detected connected to the location they were killed. HVT/HPT targets will be identified before the start of the exercise. Normally, they might be C^2 nodes, air defense artillery (ADA) systems, artillery systems, tanks, and key logistic systems.
   b. Rationale: The shorter the time interval between detection and kill, the better the staff may be in coordinating fires.
   c. Output: Picture and/or bar graph

Decision-Making

1. Sensor Coverage – OPFOR vehicles detected as well as those not detected by BLUFOR sensors during each mission.
   a. Operational definition: Location of OPFOR vehicles on the battlefield that are first detected by squadron assets. Also include location of OPFOR vehicles on the battlefield that are undetected.
   b. Rationale: If the staff is not properly deploying and monitoring performance of their sensors, then the information that is being displayed to the commander will be incomplete, which will prevent him from making a decision using all information that could be made available to him.
   c. Output: Picture

2. Multiple Fire Engagements – Number of OPFOR vehicles which were engaged multiple times during each mission.
   a. Operational definition: For each OPFOR target killed, calculate the total number of additional engagements against it by BLUFOR weapon systems after it was killed. Data collected should indicate the firing unit, echelon of its controlling headquarters, the type of weapon used, the engagement time, and should indicate at which time the OPFOR target was killed (firepower, mobility, and/or catastrophic). For each OPFOR target engaged multiple times, show its location on the battlefield and the location of the units that continued to fire on it after it was killed.
   b. Rationale: The data on multiple engagements of an OPFOR target may indicate whether the situational awareness provided by the SC^4 system and an effective unit fire coordination and distribution system reduced or prevented the needless expenditure of ammunition against targets already destroyed.
   c. Output: Picture and/or table

3. Maneuver Battle Sets – Disposition of OPFOR and BLUFOR at a specified time period.
   a. Operational definition: Location of OPFOR company command vehicles and battalion subordinate maneuver platoon leader vehicles at critical points during each mission (start of exercise, first indirect fire engagement with OPFOR, first direct fire engagement with

OPFOR, first friendly casualty, friendly losses exceed 30%, and last engagement during mission).

   b. Rationale: May indicate whether the staff estimates and other information staff members provided to the commander allowed him to make the right decision on positioning his maneuver forces prior to the start of the trial.
   c. Output: Picture

4. CSS Available Over Time – Availability of ammunition and fuel during each mission.
   a. Operational definition: Percent of critical ammunition types (to be determined prior to start of mission) for 20-minute intervals for each mission, using 60% as a base amount at any given time.
   b. Rationale: May indicate if the staff made the right decision on positioning ammunition and fuel prior to start of mission.
   c. Output: Line graph

Appendix D

Sample Automated Measure Macro

This appendix contains the Microsoft® Excel Macro, modified by Microsoft® VisualBasic®, that is used to create the bar graph for the Sensor-Shooter measure.

```
Sub MakeSENSORSHOOTERGraph()
'
' MakeSENSORSHOOTERGraph Macro
' Macro recorded 4/18/2001 by holdenb
'
  MakeSENSORSHOOTERGraph1
  MakeSENSORSHOOTERGraph2
  MakeSENSORSHOOTERGraph3
'
  Dim myFileName As String, myChart As String, myPath As String,
    myTime As String, myTitle As String, ThisFile As String
    myPath = "C:\FCC2\Results\"
  myFileName = Format(Now(), "mmddyy")
  myTime = Application.InputBox("Enter Time")
  myTitle = ActiveChart.ChartTitle.Characters.Text
  MsgBox "Saving Chart as" & myPath & myTitle & myFileName _
        & "_" & myTime, vbInformation, "Save as:"
  ThisFile = myPath & myTitle & myFileName & "_" & myTime
  Sheets("SensorShooterTimeLagGraph").Select
  Sheets("SensorShooterTimeLagGraph").Move
  ActiveWorkbook.SaveAs (ThisFile)
  ActiveWindow.Close
  Application.DisplayAlerts = True
  Windows("Sensor_Shooter_Time_Lag_Graph.xls").Activate
  ActiveWindow.Close
  Application.DisplayAlerts = False
  Windows("FCC2Macros.xls").Activate
End Sub

Sub MakeSENSORSHOOTERGraph1()
'
' Macro recorded 4/13/2001 by holdenb
' Macro revised 5/24/2001 by holdenb
' Activates data source file
  Workbooks.Open _
     "C:\FCC2\Common\Sensor_Shooter_Time_Lag_Graph.xls"
  Dim Count As Integer
  Set myRange = ActiveSheet.UsedRange
  Set FTime = myRange.Columns("A")
```

```
'Routine begins to convert times into minutes

Rows("1:1").Select
Selection.Delete Shift:=x1Up
Columns("D:D").Select
Selection.NumberFormat = "General"
Range("E1").Select

   For Each R In FTime.Cells
      R.Offset(0, 4).Select
      ActiveCell.FormulaR1C1 = "=RC[-4]-RC[-1]"
      R.Offset(0, 5).Select
      ActiveCell.FormulaR1C1 = "=HOUR(RC[-1])"
      R.Offset(0, 6).Select
      ActiveCell.FormulaR1C1 = "=MINUTE(RC[-2])"
      R.Offset(0, 7).Select
      ActiveCell.FormulaR1C1 = "=(RC[-2]*60)+RC[-1]"
      If R.Value = "" Then End

     End If

   Next R

End Sub

Sub MakeSENSORSHOOTERGraph2()

' MakeSENSORSHOOTERGraph2 Macro
' Macro revised 5/24/2001 by holdenb
'
  Windows("Sensor_Shooter_Time_Lag_Graph.xls").Activate
  Dim Count As Integer
  Set myRange1 = ActiveSheet.UsedRange
  Set FTime1 = myRange1.Columns("A")
  Worksheets("Sensor_Shooter_Time_Lag_Graph"). _
     Cells(1, 10).Value = "Time"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
     Cells(2, 10).Value = "<30"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
     Cells(3, 10).Value = "30-59"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
     Cells(4, 10).Value = "60-89"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
     Cells(5, 10).Value = "90-119"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
     Cells(6, 10).Value = "120-149"
  Worksheets("Sensor_Shooter_Time_Lag_Graph")._
```

```
      Cells(7, 10).Value = "150-179"
   Worksheets("Sensor_Shooter_Time_Lag_Graph")._
      Cells(8, 10).Value = ">180"
   Worksheets("Sensor_Shooter_Time_Lag_Graph")._
      Cells(1, 11).Value = "Number"

     Count1 = 0
     Count2 = 0
     Count3 = 0
     Count4 = 0
     Count5 = 0
     Count6 = 0
     Count7 = 0

    ActiveSheet.Cells(2, 11).Value = Count1
    ActiveSheet.Cells(3, 11).Value = Count2
    ActiveSheet.Cells(4, 11).Value = Count3
    ActiveSheet.Cells(5, 11).Value = Count4
    ActiveSheet.Cells(6, 11).Value = Count5
    ActiveSheet.Cells(7, 11).Value = Count6
    ActiveSheet.Cells(8, 11).Value = Count7

     For Each R In FTime1.Cells
         If R.Offset(0, 7).Value < 30 Then
         Count1 = Count1 + 1
         ActiveSheet.Cells(2, 11).Value = Count1
         Else
         If R.Offset(0, 7).Value >= 30 And R.Offset(0, 7) < 60
Then
         Count2 = Count2 + 1
         ActiveSheet.Cells(3, 11).Value = Count2
         Else
         If R.Offset(0, 7).Value >= 60 And R.Offset(0, 7) < 90
Then
         Count3 = Count3 + 1
         ActiveSheet.Cells(4, 11).Value = Count3
         Else
         If R.Offset(0, 7).Value >= 90 And R.Offset(0, 7) < 120
Then
         Count4 = Count4 + 1
         ActiveSheet.Cells(5, 11).Value = Count4
         Else
         If R.Offset(0, 7).Value >= 120 And R.Offset(0, 7) < 150
Then
         Count5 = Count5 + 1
         ActiveSheet.Cells(6, 11).Value = Count5
         Else
```

```
        If R.Offset(0, 7).Value >= 150 And R.Offset(0, 7) < 180
Then
        Count6 = Count6 + 1
        ActiveSheet.Cells(7, 11).Value = Count6
        Else
        If R.Offset(0, 7).Value >= 180 Then
        Count7 = Count7 + 1
        ActiveSheet.Cells(8, 11).Value = Count7

        End If
        End If
        End If
        End If
        End If
        End If
        End If
    Next R

End Sub

Sub MakeSENSORSHOOTERGraph3()

' MakeSENSORSHOOTERGraph1 Macro
' Macro recorded 4/13/2001 by holdenb
' Macro revised 5/24/2001 by holdenb

'Creates Bar Chart
    Charts.Add
    ActiveChart.ChartType = xlColumnClustered
   ActiveChart.SetSourceData
     Source:=Sheets("Sensor_Shooter_Time_Lag_Graph").Range("J1:K
     8"), PlotBy:=xlColumns
    ActiveChart.Location Where:=xlLocationAsNewSheet, Name:= _
        "SensorShooterTimeLagGraph"
    With ActiveChart
        .HasTitle = True
        .ChartTitle.Characters.Text = "Sensor - Shooter Time
Lag"
        .Axes(xlCategory, xlPrimary).HasTitle = True
        .Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text =
_
        "Time (Minutes) from Detection to Kill"
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text =
"Number"
    End With
    With ActiveChart.Axes(xlCategory)
```

```
        .HasMajorGridlines = False
        .HasMinorGridlines = False
    End With
    With ActiveChart.Axes(xlValue)
        .HasMajorGridlines = True
        .HasMinorGridlines = False
    End With
    ActiveChart.HasLegend = False
    ActiveChart.PlotArea.Select
    With Selection.Border
        .ColorIndex = 16
        .Weight = xlThin
        .LineStyle = xlContinuous
    End With
    With Selection.Interior
        .ColorIndex = 2
        .PatternColorIndex = 1
        .Pattern = xlSolid
    End With
    ActiveChart.Axes(xlValue).AxisTitle.Select
    With Selection
        .HorizontalAlignment = xlCenter
        .VerticalAlignment = xlCenter
        .Orientation = xlVertical
    End With
    ActiveChart.ChartTitle.Select
    Selection.AutoScaleFont = True
    With Selection.Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 14
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlUnderlineStyleNone
        .ColorIndex = xlAutomatic
        .Background = xlAutomatic
    End With
    ActiveChart.SeriesCollection(1).Select
    ActiveChart.SeriesCollection(1).ApplyDataLabels
Type:=xlDataLabelsShowValue,
        AutoText:=True, LegendKey:=False
    ActiveChart.SeriesCollection(1).ApplyDataLabels
Type:=xlDataLabelsShowNone,
        AutoText:=True, LegendKey:=False
```

```
    ActiveChart.PlotArea.Select
    ActiveChart.ChartArea.Select
    ActiveChart.Deselect
End Sub
```